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FEBRUARY 1960
VOLUME 3 • NUMBER 2

- Antenna Measurements · Part I
- Ferroelectrics at Microwave Frequencies
- Noise Temperature in Passive Circuits

the microwave journal

MAR 3 1960
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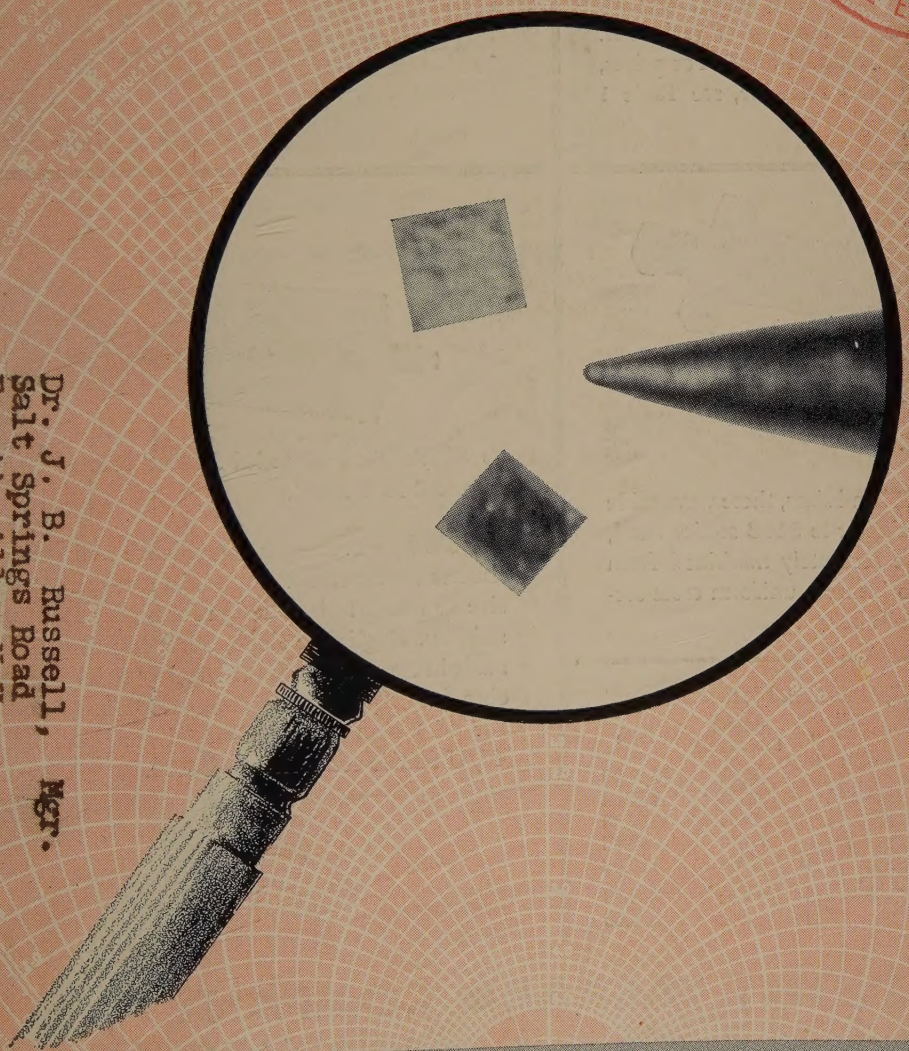
GENERAL ELECTRIC COMPANY



Dr. J. B. Russell, Mgr.
Salt Springs Road
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Also In This Issue . . .

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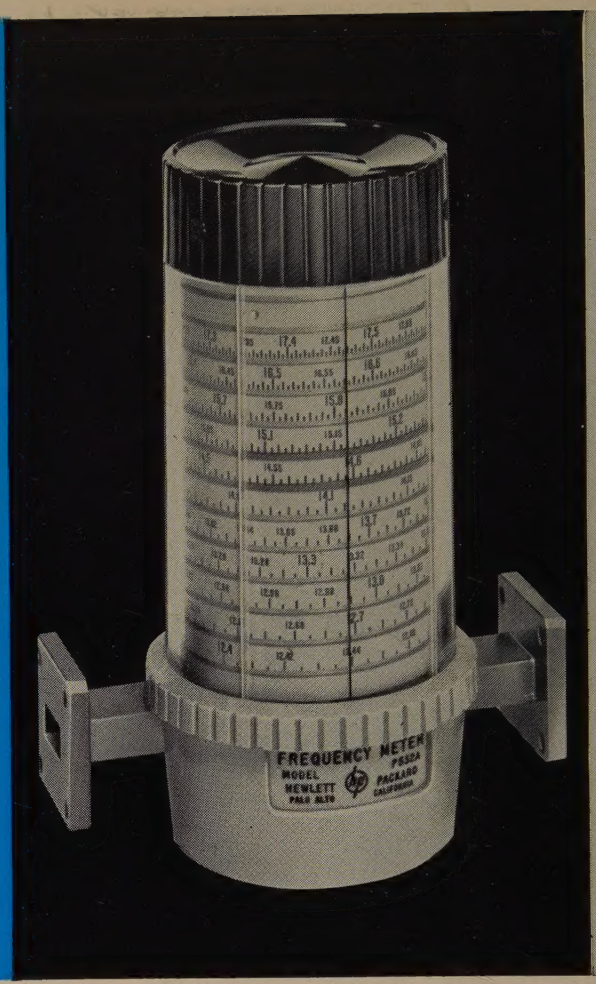

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On models 532A (H through R band) frequency is read directly in KMC on the large, precisely-calibrated spiral scale. No charts or interpolation are required. Accuracy is high, typically 0.1%.

Model 532A Frequency Meters comprise a special waveguide section mounting a high Q resonant cavity tuned by a choke plunger. No sliding contacts are used, and the waveguide section transmits virtually full power at resonance. A dip in output indicates resonance. Tuning is by a precision lead screw, spring loaded to eliminate backlash. Scale lengths of 77" calibrated in 5 MC increments are typical.

For J band work (5.20 to 8.20 KMC) Model 530 Frequency Meters are offered (see Table). These instruments are similar to Model 532A except tuning is by a micrometer, and readings are converted to frequency by a chart on the instrument.

SPECIFICATIONS

Model	Accuracy	Frequency Range KMC	Fits Waveguide Size (in.)	Length (in.)	Price
J530A	0.1%	5.85 - 8.20	1½ x ¾	4	$120.00
J530B	0.1%	5.20 - 7.05	1½ x ¾	4	150.00
H532A	0.08%	7.05 - 10.0	1¼ x ⅝	6¼	195.00
X532A	0.08%	8.20 - 12.4	1 x ½	4½	150.00
P532A	0.1%	12.4 - 18.0	.702 x .391	4½	210.00
K532A	0.1%	18.0 - 26.5	½ x ¼	4½	230.00
R532A	0.2%	26.5 - 40.0	.360 x .220	4½	250.00

Other specifications: Models 532A: Resetability 0.01%, backlash 0.005%, SWR at resonance 1.3:1 approximately.

For complete details, call your hp representative or write direct.

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hp **complete instrumentation for microwave measurements**

Source of Microwave Radiation

What is a Microwave Radiometer?

The fundamental ingredients of any microwave radiometer consist of an antenna, an amplifier, a detector, and an indicator. From a thermodynamic standpoint the antenna may be considered as a device which transports its radiation resistance at the input terminals of the receiver into a thermal reservoir contained within the volume of space "observed" by the antenna and determined by its directive characteristics. If we then assume that the observed medium is a composite black body reservoir at some temperature T, then the temperature of the radiation resistance of the antenna will come into equilibrium with the temperature of this reservoir. The amplifier portion of the receiver then amplifies the power presented to its input terminals by the radiation resistance. This power level is the well known Johnson noise power KTB where K is Boltzmann's constant, T is the equivalent temperature of the radiation resistance and B the predetection bandwidth of the amplifying device. The power input to the amplifier is then equivalent to the power output of a resistor matched to the receiver input, and immersed in a thermal reservoir at temperature T. Since this power level is directly proportional to the temperature of the reservoir, the signal input can be expressed in temperature units (of degrees Kelvin).

In the Rayleigh-Jeans approximation for the brightness of Planck radiation, the brightness per unit cycle is inversely proportional to the square of the wavelength, whereas Johnson noise power is independent of frequency and dependent only upon temperature. The thermodynamic balance of the two sources of power is obtained, in a receiving system, through the wavelength characteristic of the average antenna cross section. When performing the integration of the product of brightness per unit wavelength and antenna cross section, over the bandwidth of the receiver and the solid angle of the antenna aperture, the wavelength-dependent terms cancel. Hence an antenna totally "immersed" in a black body at temperature T will contribute a constant power output at its terminals, independent of frequency.

In summary, the logic is as follows: The power incident upon the antenna aperture within the bandwidth of the receiving system produces a thermal bath for the radiation resistance of the antenna, at the temperature of the "composite equivalent" black body viewed by the antenna. This antenna temperature is then transmitted to the amplifier via the "Johnson noise mechanism," where it is amplified in the presence of the noise power attributable to the man-made circuitry.

The signal strength is recorded in temperature units (degrees Kelvin).

Ewen Knight radiometers of the HII series are capable of detecting temperature changes at the receiver input terminals as low as 0.01°K, which is approximately 10^{-25} watts/cps.

Ewen Knight CORPORATION

AT THE FRONTIERS OF Electronics

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Circle Reader Service Card 1

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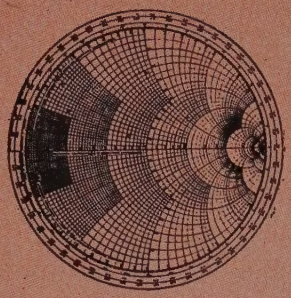

the microwave journal

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Boston 19, Massachusetts
HIghlands 5-6660
Direct Dial Code: 617

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"the microwave journal" is published monthly by Horizon House Inc., William Bazz President. Executive Editorial offices at 160 Warren Street, Boston 19, Mass., telepho HIghlands 5-6660.

"the microwave journal" is issued without charge upon written request to qualified pe sons working at microwave frequencies in the fields of antennas and propagati electrons and solid state devices, systems, and components manufacturers in the co tinental United States and Canada, including governmental and university installatio Other subscriptions — continental United States, $10 per year, single copy, $1 wh available. In Canada, $15 per year, single copy, $1.50 when available. Other fore countries, $20 per year, single copy, $2 when available. **Copyright February 1960 Horizon House Inc.** **Accepted as controlled circulation publication at Boston, Mass.**

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SIX VSWR AMPLIFIER FEATURES

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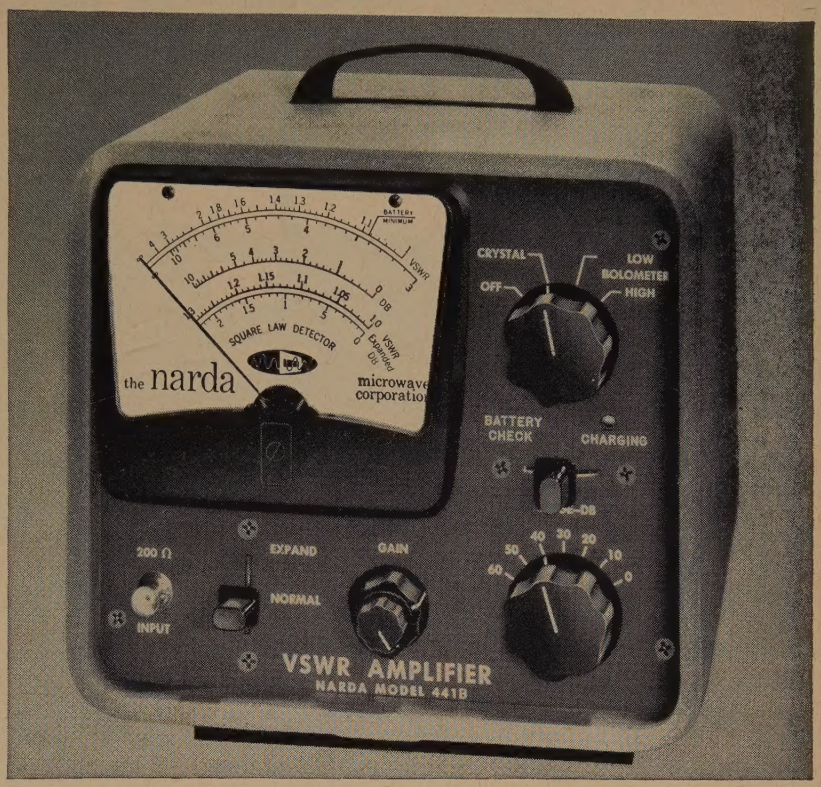

Model 441B—$225

ow you can get a completely portable battery-erated VSWR Amplifier offering complete protec-n against bolometer burnout at the same time!

rda's Model 441B is supplied with nickel-cadmium tteries, providing complete freedom from line tage deviations. Batteries recharge automatically en unit is plugged in; provision is built-in to show te of battery charge. A special protective circuit permits switching and connect-disconnect with no danger of bolometer burnout. Provision is made for both crystals and high **and** low current bolometers.

Full sensitivity is provided over both normal and expanded scales; eliminates switching attenuation range. Other features are shown on this page; for complete information and a free copy of our latest catalog, write to us at: Department MJ-10.

EATURES:

ENSITIVITY:	0.1 microvolts at 200 ohms for full scale.
REQUENCY:	1,000 cps ± 1% (plug-in frequency networks available for 315-4,000 cps and broad-band applications)
ANDWIDTH:	25-30 cps
ANGE:	72 db (60 db in 10 db steps, 11 db continuous)
CCURACY:	± 0.1 db per step • ± 0.2 db maximum cumulative • meter linearity: 1% of full scale

the narda microwave corporation

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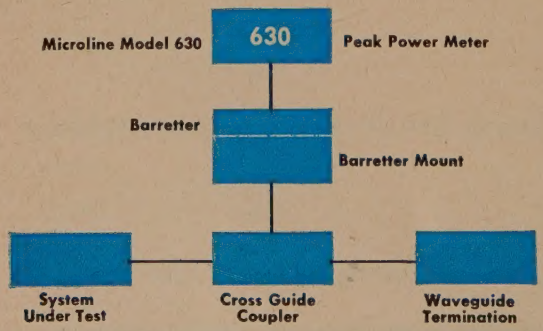
NOW—simple, accurate, direct PEAK POWER

PEAK POWER may now be measured directly—with speed and simplicity—using integrated Microline® equipment from Sperry. Unlike other power measurement techniques which require a wattmeter bridge or calorimetric load, plus an oscilloscope and synchroscope—just four additional components are necessary when using the Microline Model 630: a crossguide coupler, a termination, a barretter mount, and a barretter.

DIRECT READING—Pulsed microwave energy is coupled from the system under test into the crossguide directional coupler, and a high power termination connected to the coupler's primary output. The suitably attenuated energy is fed from the secondary arm directly into a waveguide barretter mount. The output from the barretter and barretter mount is fed coaxially to the input of the Microline Model 630, and peak power is read directly from the scale. The measurement is simple, positive and precise.



THE "630" METER consists of an active differentiator, video amplifier, peak reading voltmeter, and a calibration circuit which eliminates calibration down-time.

THE BARRETTER, in a suitable mount, is subjected to pulses microwave energy from the system under test. The barrett is operated in a constant current circuit and its resistan change is a function of temperature, which is determin by total power. The voltage waveform out of the barrett mount will be sawtooth with an essentially linear rise wh a pulse is applied and an exponential decay as a resistan of the barretter returns toward normal after the pulse h decayed. The slope of the waveform is a function of pe power. The sawtooth waveform out of the barretter mou is fed into the differentiator, the output of which is a vid pulse. This pulse is an accurate replica of the envelope the microwave pulse impinging on the barretter. The amp tude of the video pulse is proportional to microwave pe power.

DIFFERENTIATOR OUTPUT is amplified in the video amplifi to provide sufficient signal amplitude to properly operate peak reading voltmeter circuit. A portion of the output the video amplifier is brought out to a front panel jack provide a connection for viewing the video pulse with external oscilloscope, if desired.

THE PEAK READING VOLTMETER utilizes a novel amplifi feedback circuit which provides a stable and accurate mea of measuring the peak voltage of a video pulse over a co siderable range of pulse width and repetition rates. T output of the peak voltmeter circuit is a front panel me which has been calibrated in milliwatts.

Address inquiries to Manufacturers' Representatives: Gera B. Miller Co., P. O. Box 1471, Hollywood 28, Californ Louis A. Garten & Associates, 645 Eagle Rock Ave., W Orange, New Jersey; Technical Instruments, Inc., 90 Ma St., Reading, Mass.

MEASUREMENTS

BARRETTERS

Model	Nominal Resistance (ohms)	Price
825	200 for Peak Power Measurements	$ 14.
823	200 for Peak Power Measurements	14.

ATTENUATORS

Model	Description	Frequency Range-kmc	Attenuation Range-db	Waveguide Size	Fittings	Price
134	Calibrated ± .5db	8.5-9.6	2-45	1"x½"	UG-39/U	$220.
152A	Variable	8.1-12.4	0.5-20	1"x½"	UG-39/U	45.
375A	Variable	12.4-18.0	1-15	0.702"x0.391"	UG-419/U	75.
374A	Variable	26.5-40	1-20	0.360"x0.220"	UG-599/U	60.

DIRECTIONAL COUPLERS

Model	Description	Frequency Range	Attenuation-db	Fittings	Price
517	⅞" Coaxial	.240-.480	30	UG-46/U*	$150.
519	⅞" Coaxial	.480-.960	30	UG-46/U*	150.
467	⅞" Coaxial	1.99-4.0	20-30-40	UG-46/U*	150.
306	3"x1½" Waveguide	2.6-4.0	30	UG-214/U	100.
544	3"x1½" Waveguide	2.6-4.0	40	UG-214/U	150.
545	3"x1½" Waveguide	2.6-4.0	50	UG-214/U	150.
233	2"x1" Waveguide	4.0-6.0	24	UG-149A/U	85.
321	2"x1" Waveguide	4.0-6.0	30	UG-149A/U	125.
322	2"x1" Waveguide	4.0-6.0	40	UG-149A/U	125.
209	1½"x¾" Waveguide	5.3-8.1	24	UG-344/U	75.
237	1½"x¾" Waveguide	5.3-8.1	30	UG-344/U	85.
546	1¼"x⅝" Waveguide	7-10	30	UG-51/U	85.
547	1¼"x⅝" Waveguide	7-10	40	UG-51/U	85.
235	1"x½" Waveguide	8.1-12.4	20	UG-39/U	65.
419	1"x½" Waveguide	8.1-12.4	30	UG-39/U	65.
234	1"x½" Waveguide	8.1-12.4	40	UG-39/U	65.
388	0.702"x0.390" Waveguide	12.4-17.0	20	UG-419/U	65.
413A	½"x¼" Waveguide	18.0-26.5	20	UG-595/U	65.
414A	½"x¼" Waveguide	18.0-26.5	30	UG-595/U	65.
405A	0.360"x0.220" Waveguide	26.5-36.0	20	UG-599/U	80.
429A	0.360"x0.220" Waveguide	26.5-40.0	10	UG-599/U	85.

*Input fitting. Main line output UG-45/U. Secondary line output, UG-46/U. Adapters (Models 352A and 217) convert these units to Type N.

BARRETTER MOUNTS

Model	Line Size	Barretter Type*	Frequency Range-kmc	Max. VSWR	Fittings Input	Fittings Output	Price
554	⅞" Coax.	811B/550T	.82-2.0	1.8/1.5	UG-46/U	BNC	$175.
245	2"x1"	821B	3.7-4.5	1.5	UG-149A/U	UHF	35.
184	1"x½"	821B	8.5-9.6	1.5	UG-39/U	UHF	70.
423A	2"x1"	543T	5.0-5.9	1.5	UG-149/U	BNC	135.
219C	1"x½"	—T	8.5-9.6	1.5	UG-39/U	BNC	130.

*B-Barretter, T-Thermistor

HIGH-POWER WAVEGUIDE TERMINATIONS

Model	Size	Frequency (kmc)	Power Capacity Av. (w)	Power Capacity Peak (kw)	Max. VSWR	Fittings	Price
563	3"x1½"	2.6-4.0	2200	2200	1.15	UG-584/U	$150.
564	2"x1"	3.95-6.0	1500	1500	1.15	UG-407/U	140.
565	1¼"x⅝"	7.0-10.0	350	350	1.15	UG-138/U	100.
566	1"x½"	8.1-12.4	300	300	1.15	UG-135/U	85.

LOW-POWER WAVEGUIDE TERMINATIONS

Model	Size	Frequency Range-kmc	Power Capacity	Max. VSWR	Fittings	Price
308	3"x1½"	2.6-4.0	1	1.04	UG-214/U	$ 40.
370	0.702"x0.391"	12.4-18.0	0.5	1.05	UG-419/U	25.
418A	½"x¼"	18.0-26.5	0.5	1.07	UG-595/U	30.
369A	0.360"x0.220"	26.5-40.0	0.5	1.10	UG-599/U	35.
637	⅞" Coaxial	.65-3.5	12	1.4	UG-46/U	55.

SPERRY

MICROVIEWS OF THE MONTH

39 ▶ **ANTENNA MEASUREMENTS - Part I**

J. Searcy Hollis

Written for the individual whose experience has been largely in some other fields of electronics, this paper reviews some of the factors associated with the measurement of radiation characteristics of antennas. Part I, appearing in this issue, presents a brief review of basic theory, with copious references to standard antenna texts and periodicals, and a discussion of some practical aspects of problems associated with antenna measurements.

47 ▶ **FERROELECTRICS AT MICROWAVE FREQUENCIES**

W. J. Gemulla and R. D. Hall

Solid state devices of many types are now in common use in microwave equipment. This article is about a class of materials, the ferroelectrics, which have received little attention at microwave frequencies. Their variable dielectric constant, controllable by a dc bias, may bring a new degree of freedom to microwave circuit design.

52 ▶ **NOISE TEMPERATURE IN PASSIVE CIRCUITS**

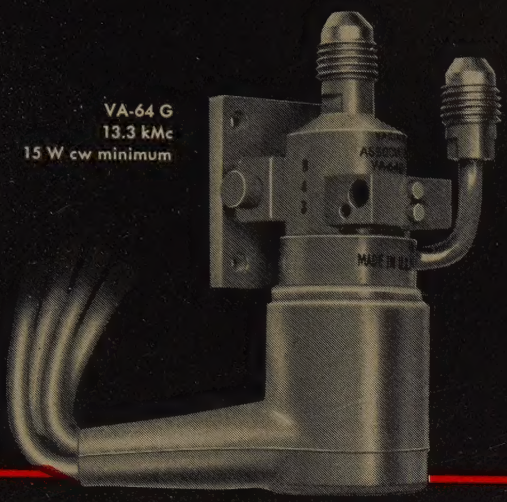
Henry H. Grimm

Various points of view concerning the temperature to be associated with passive circuits are discussed. Three temperatures, the effective temperature, the incremental temperature, and an excess temperature are defined and interrelated.

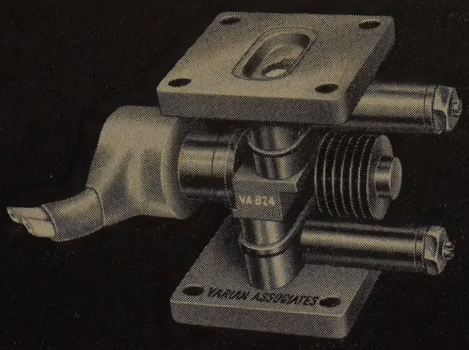
OUR COVER

The tiny cubes (0.010 inch on a side) in the photomicrograph are voltage-variable microwave capacitors. Each cube is of ferroelectric ceramic and has two silvered surfaces which are the capacitor plates. Capacitance is controlled by dc voltage applied to the silvered surfaces.

The capacitors are compared with the point of a pin at about fifty diameters magnification. See page 47.

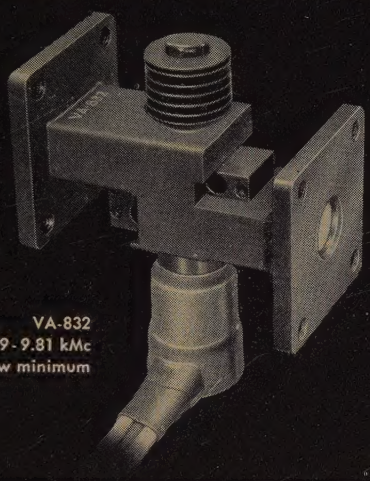


VA-64 G
13.3 kMc
15 W cw minimum

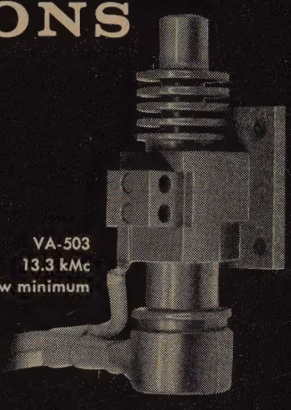


VA-824 B
9.78 - 9.82 kMc
2 W cw minimum

NEW VARIAN KLYSTRONS



VA-832
9.79 - 9.81 kMc
6 W cw minimum



VA-503
13.3 kMc
1 W cw minimum

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The four klystrons illustrated are only a sample of the hundreds of types Varian makes for Missile, Radar, Communications, Test & Instrumentation applications. They are described and pictured in our new catalog.

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PAPER REVIEWS

Some of our readers have expressed surprise when they learned that technical articles appearing in *the microwave journal* were subjected to careful editorial review. So that there will be no further doubt on this matter, a brief explanation of our procedure follows:

Each paper receives at least two comprehensive reviews. Most of the reviews are by the members of the editorial board. In cases where the editorial board member feels someone else is better qualified to review a specific paper, he enlists expert assistance.

When the reviews are completed — in secrecy — they are returned for an editorial decision. Often both reviews are complimentary and favorable and the paper is accepted with no further revisions. The author is so notified and a tentative date of publication is set.

More often the reviews will suggest changes, deletions, or additions. The reviewers' recommendations are then sent to the author. The author usually makes the suggested modifications and re-submits the paper. If the changes are minor and obvious, the paper is then accepted. The author is notified and a tentative date of publication is set. If the changes are major, the paper is re-reviewed, and the process repeated until it is accepted or rejected.

Occasionally two reviews will be returned with exactly opposite opinions. In a case of this sort if the reason for the difference of opinions is not clear, the paper is subjected to still a third review. The final disposition of technically controversial papers depends on many factors which are too involved for this short discussion.

Often both reviews will come back negative in which case there is no alternative but to notify the author.

During the entire reviewing process, the reviewers do not see each other's review. In fact one reviewer will not usually know who else is reviewing a given paper. The names of the reviewers are never revealed to the authors.

The process is complex but very carefully managed. It becomes somewhat involved when there are many revisions and the papers travel back and forth between the author, the editorial office, and the reviewers.

Yet with all the complications and involved procedures, the most difficult thing of all is to write to an author notifying him that his paper has been rejected.

All of us on *the microwave journal* share a feeling of pride at the news that our Associate Editor, Dr. Ben Lax, has been awarded the 1960 Oliver E. Buckley Solid State Physics prize of The American Physical Society. The award was for his "fundamental contributions in microwave and infrared spectroscopy of semiconductors." We are indeed fortunate that Ben has found time in his career to be one of those who directs the editorial policies of our magazine.

Ted Saad

it has everything...

VERSATILITY

RELIABILITY

STABILITY

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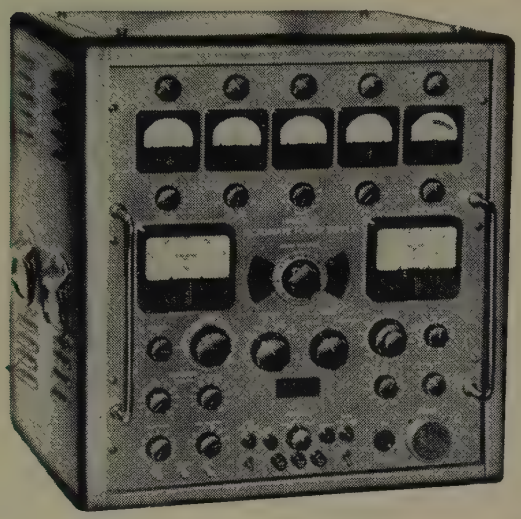

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is a single *power source for microwave tubes.*

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Biography By
DAVID SIMON

"HEIL HITLER!" HAD BECOME an all-too-common greeting and everywhere the way of life was being changed — slowly, carefully, imperceptibly at first; then faster, more flagrantly and blatantly. This was the environment in Berlin in the early 1930's, a period deeply imbedded in the memory of Rudolf G. E. Hutter. As a physics and mathematics student at the University of Berlin, Hutter saw the Nazi Party work its way into power, and the war machine take shape. It wasn't until late in the decade that domination of the citizen by the fanatical element reached intolerable dimensions; in the early thirties caution was necessary, but life was not yet oppressive.

In 1932, Rudy met and began dating Ruth Fraenkel, also a math student at the University of Berlin. Ruth was Jewish, and even that early in the decade discrimination existed. She was issued for example, a yellow student body card, markedly different from the grey one which most students carried. In the years that followed, this religious difference meant that the young couple had to date carefully, seldom in public; for being seen with Ruth and her friends could have meant arrest for Rudy. The Nazis had branded this "behaving as a traitor to the Aryan race" and expressly forbade it in the Nürnberg Laws. But Rudy was fortunate: as his friends often told him, he looked Jewish when in Jewish company, Aryan when with Aryans. He was thus able to go on biking and hiking trips, picnics and excursions in the countryside around Berlin with Ruth and her companions, where the chances that he'd be recognized were reduced. Thinking back on this period, Hutter shudders slightly. "The risks were actually much greater than we admitted to ourselves at the time; in ways it was almost a game keeping out of the way of the Nazis. Sometimes, when we were all marched off to hear Hitler speak I would duck into a rest station. When my group was well out of sight I would double back to a pre-arranged hiding place and spend the afternoon with Ruth. I wouldn't be so daring now, and if I had that period to live over again . . . I just don't know."

"That period" lasted six years. Ruth was thrown out of college before she could graduate, as the Nazis deepened their anti-Semitic hate campaign in order to destroy the influence of the Jews in Germany, many of whom secured powerful positions under the Weimar Republic. For a while she taught in a Jewish school, but by 1938 Germany Jews were being treated like a lower form of life, with very little freedom, and abuse from every quarter. Ruth realized that if she were going to leave she had better do so quickly. Passports were no longer being issued to Jews but Ruth had obtained one in 1933, and it still had a few months to run. A visa was quickly issued by an amicable unconcerned government underling named Goebbels, who quickly explained that he was "no relation to the famous one." She left the country in August, and went to stay with relatives in Baltimore, Maryland. The trip there was not without unpleasantness: a German customs agent at the German-Dutch border, powerless to detain her since her papers were in order, got his satisfaction by opening her baggage and strewing the contents around the dirty floor of the station. With unaccustomed bravado, Ruth snapped at him "I've had enough of your kind," changed her plans to wait overnight for the morning express, and instead took the first local into the Netherlands and freedom.

In retrospect, Ruth's timing seems almost psychic, for mere ten weeks later organized bands of Nazis all over Germany began what has been called "an anti-Semitic orgy of destruction, looting, and incendiarism," wrecking 5 synagogues, smashing windows and destroying goods in every Jewish shop. A series of decrees followed which prohibited Jews from further retail trade, banned them from theaters, movies, concert halls, cafes, and certain areas of the city, and forced them to move from the better resi

(*Continued on page 12*)

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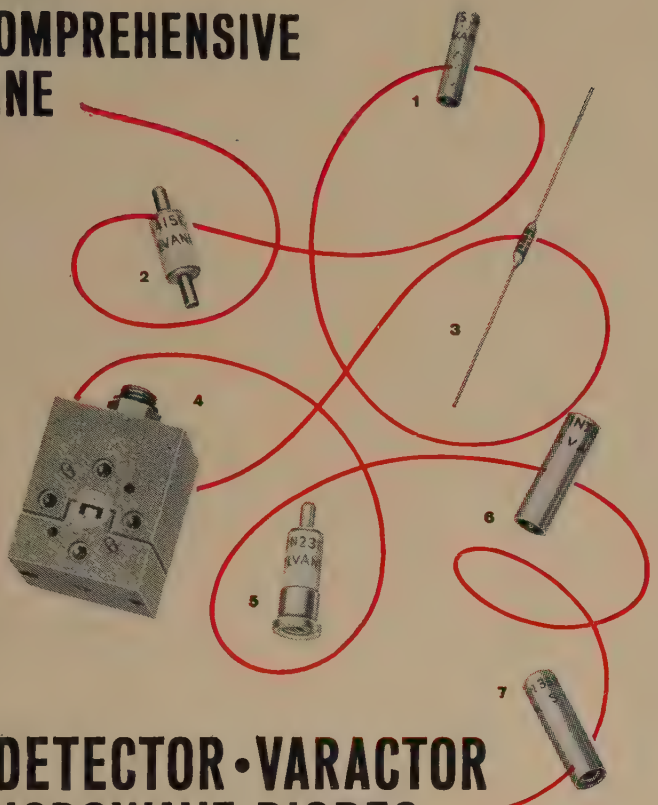

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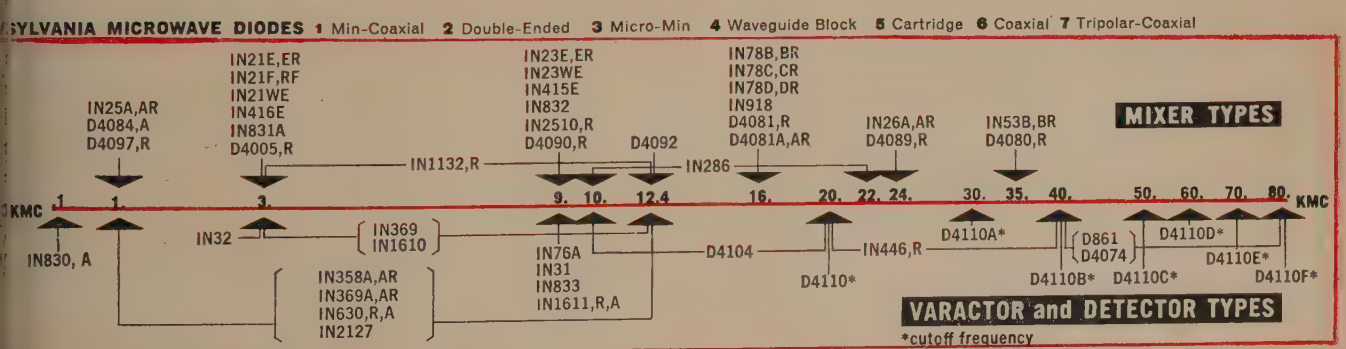

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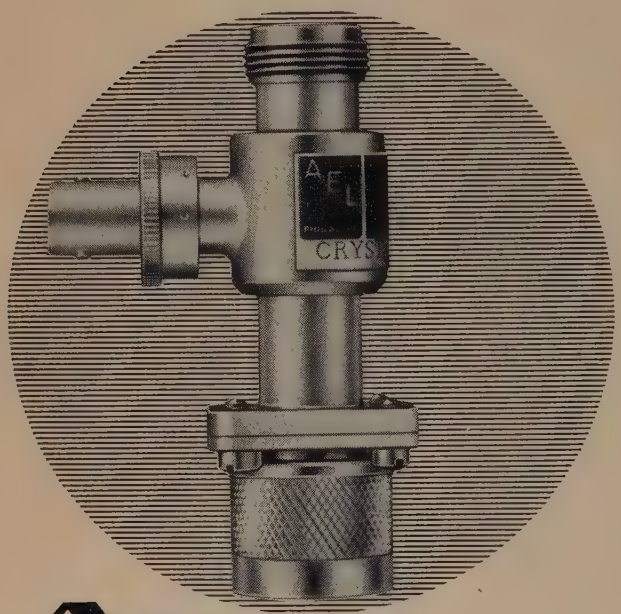

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Dr. Hutter

(*Continued from page 10*)

tial districts. They were thus restricted to "a pitiful ghetto like existence reminiscent of the Middle Ages."

One of the first things that struck Ruth outside of Ger many was that the rest of the world was talking about war a subject which was still an infrequent topic of conversa tion for most Germans, who didn't realize how soon it wa to be upon them. Strangely, perhaps the result of carefu planning by Hitler and Goebbels, his propaganda minister the idea of war seemed remote and distant in spite of the preparations and the growing military character of the regime.

Since she and Rudy had been planning to get married the fear that war would trap him in Germany alarmed her and she immediately began bombarding Rudy with letter describing the "beautiful silver clouds" over Baltimore This meant "Get out NOW!" and was part of a code th two had arranged prior to Ruth's departure, little expecting how soon it would be used.

Rudy had completed his work at the University in 1936 and had passed the State Exam. His original plan had been to follow up with teacher training, but by the time hi college work was completed he knew that eventually he'd want to come to the States, and he felt he'd find work mor readily as an engineer than as a teacher. The solution world-renowned Telefunken, G.M.B.H., where he worked for two years, until the "silver cloud" letters began to ar rive. This was September 1938, and the Nazi leader knowing they would soon be engaged in an all-out war suddenly announced that engineers could no longer emi grate. Rudy resorted to a ruse: he obtained a one-mont passport for a visit to Denmark, and through a stroke o luck, a chance acquaintance notified a group of Quaker in Denmark that he was coming, and needed assistance He turned up there in the midst of an international meetin of Quakers and sat tired and hungry through a day o prayer meetings: silence, interrupted only by occasiona religious remarks from participants. Since each spoke i his native tongue, Rudy understood very little of wha transpired.

When, at last, he was able to make known who he wa he received cooperation and assistance to a degree he hadn dared hope for. But finding a country to which he coul escape turned out to be very difficult since his passport wa valid only for travel in Denmark. When his passport wa about to expire it began to look as though his efforts t elude the Nazis had been in vain; with but a few days lef one of the Quaker women remembered that a teacher o hers was the aunt of a high government official. Leavin Rudy to watch the meal she had been preparing, the kind hearted woman rushed to her teacher's house, and within forty-eight hours, Rudy was granted permission to remai two more months in spite of his invalid passport. Ther was a catch, though: Rudy had to sign a paper agreein to arrest and deportation to Germany if he was still o Danish soil at the end of the two-month period. Since th Nazis had learned of his plans to marry a non-Aryan, re turn to Germany would have been fatal.

In Baltimore, Ruth was well aware of her fiance's pligh

(*Continued on page 14*)

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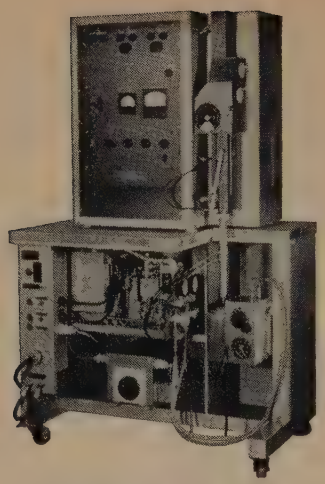

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Dr. Hutter

(*Continued from page 12*)

and was making every effort to find a way for him to get out. Her investigations bore fruit, as Rudy learned in a wire from her: "Check on Philippines. Understand you can get there without a passport." Within forty-eight hours she had the answer she had hoped for: "Can get into Philippines . . ." the message began. She reread it, just to make sure; then continued ". . . if I have $500. Please wire." (The wire didn't explain the need for such a large sum but soon afterward a letter did: local authorities in the Philippines required immigrants to show that amount as an indication that they would not become wards of the government.) Ruth borrowed the money from a cousin and rushed it to Denmark.

The trip to the Philippines is recalled with mixed emotions: a 44-day cruise on a Swedish freighter through the Mediterranean, Suez Canal, Indian Ocean, and Pacific with stops at Algiers, Port Said, the Sudan, Singapore and a dozen other interesting ports. Potentially a time for unwinding the tensions built up by the weeks of uncertainty and waiting, it was in actuality half-filled with rough weather and sea-sickness. And the exotic ports remain just names, and sky lines in the distances for with an invalid passport, Rudy was unable to leave the ship until they reached Manila.

The first two weeks in Manila provided at long last a tranquilizing period — the first time Rudy had been able to relax in many years. Rudy arrived with the $500 Ruth had sent, and "with that amount of money weighing down my pocket, I was in no hurry to get a job. I moved into a small but comfortable apartment, stocked the pantry with top quality foods, and enjoyed myself." But for a man of Rudy's energy and ambition such an unproductive state is doomed to be nothing more than transitory, and within a few days he was out looking for work. When another applicant was selected over him for a vacancy at the local university, Rudy accepted a position as Chief Engineer on radio station KZIB. "When I say that one of my major jobs was keeping bugs out of the equipment I mean it literally, not figuratively," he relates. "I spent a great deal of time rushing from studio to transmitter, and removing the remains of large electrocuted bugs from high voltage terminals." But not all the bugs interrupted transmission; some were eaten by the lizards that crawled along the floor and clung to the wall. Snakes abounded too, but they didn't get in the way very often.

While working at the station, Rudy renewed his efforts to get into the States. A check with the State Department office at Manila brought the word that no quotas were then available, and that there was no information as to when they would be. Since it appeared that he would be stuck in Manila for quite some time he and Ruth agreed that she would join him there. She packed up and started the journey, but before she got very far Rudy heard a report that quotas to the U. S. had been made available to Germans outside Germany. This word reached him on a Sunday, and he was unable to contact any State Department officials. Rather than risk

(*Continued on page 16*)

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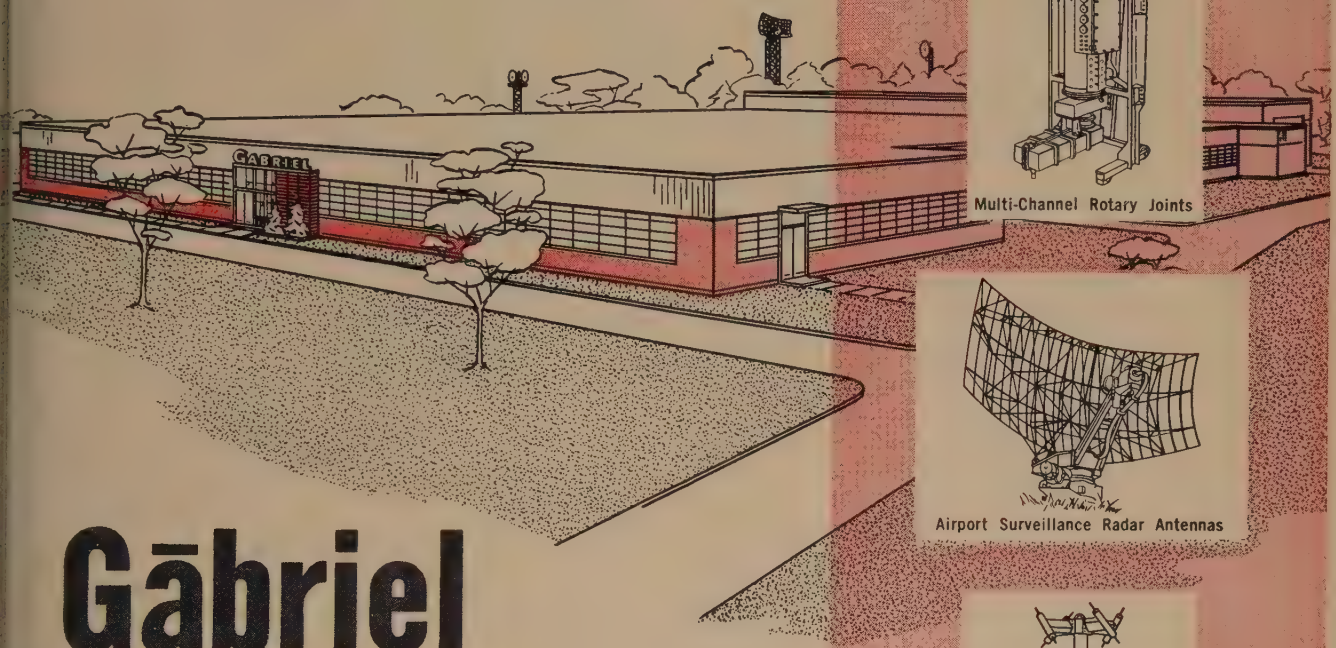

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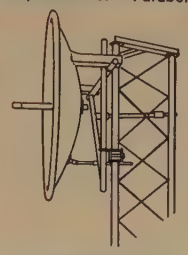

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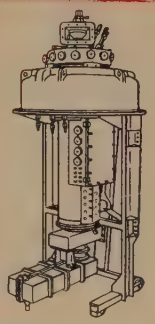

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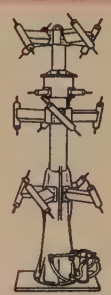

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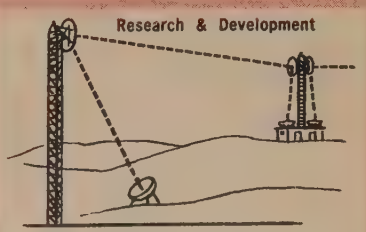

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Dr. Hutter

(*Continued from page 14*)

having Ruth arrive in the Philippines when he might be getting a quota, Rudy intercepted her in San Francisco, advising her to wait for further word.

Early Monday morning Rudy contacted the top diplomatic representative in the Philippines and heard the disheartening news: "We've heard that rumor, too; but it has no foundation. The policy is the same as it has been, and it could be months or years before you can get into the United States." A tinny, mechanical "Sorry" rang in Rudy's ear as he replaced the receiver, as though the official had said it so often that he had forgotten its meaning.

With this dismal outlook there was no reason to hold up Ruth's trip any longer, and Rudy wired her to continue.

Ruth arrived in November 1939, and they were married almost immediately. Most of their funds were expended in paying for furniture, and for the first month's rent in the new apartment. Ruth was economy-minded — much more so than Rudy had been — and one of the first things she did was to replace the fancy foods Rudy had grown accustomed to, with plainer varieties and less expensive brands.

The timing of the next phase in this saga is a little uncertain. Ruth remembers it as hours after she arrived; Rudy insists it was two or three days. In any case, Ruth had been in Manila just long enough for them to get married and spend all their money, when Rudy received a phone call, heard a familiar voice happily announce that Rudy had just been granted a quota and could leave for America immediately. The voice, of course, belonged to the same official who had said only a short time earlier that the rumor of an early quota was untrue. Whether the rumor was out before the diplomatic corps got the official announcement, or whether the official was not up to date on policy changes, Rudy was unable to learn. What he did learn was that his quota assignment would be firm for four months, at which time he could get, upon application, one four-month extension. After that, his quota number would be given to someone else.

This meant that the newly-weds had eight months in which to save enough money for passage to the States. Ruth got a teaching job, tightened the economy measures, and stashed away as much of the weekly income as possible. Even so, they had just barely enough for the trip at the end of the eight months.

It was early 1940 when they arrived in San Francisco. Rudy began looking for a job, but the results were very discouraging. No one understood the significance of the State Exam Rudy had taken at the University of Berlin, and even when he wrote out details of all his major courses, prospective employers didn't seem impressed. But more important was the fact that Hitler had loosed his massive war machine on Europe, and anti-German feeling was running high in America. Officially, it mattered little that Rudy was opposed violently to everything the Nazis stood for. Everyone with an accent was suspect; questions of ideology and loyalties seldom got asked.

The disappointments were many and bitter. Rudy still remembers in vivid detail hearing about a radio station being started in Stockton, taking a long, hot exhausting bus ride, walking for an hour to overcome nausea, then finding the man to whom he'd been referred, only to learn that the idea of building a station had long since been abandoned.

After repeated rejection, Rudy finally decided that he would be much better off with an American Ph.D., so that his educational qualifications would meet with greater understanding and acceptance. To get the Ph.D. would be a relatively simple matter: as a result of his State Exam all he need do, a Stanford official informed him, was write a thesis and spend three terms in residence.

Rudy enrolled at Stanford while Ruth sold men's clothing and baby-sat to support them. To supplement the income, Rudy went to work for a professor, building a device for the automatic plotting of antenna patterns. The device was too costly and cumbersome to catch on, but Rudy received $25 a month while the job lasted. That summer he wired and wound coils for police radios at a nearby engineering firm. "We lived like kings," Rudy recalls, "and every time one of us got a raise, we'd move to a better apartment."

Shortly after the beginning of the third term at Stanford, the University brought in an electron microscope to design and build a number of units for them. Rudy became a technical assistant and research associate, responsible for the design and construction of highly regulated power supplies. Through this relationship he became absorbed in the problems of electron optics, began to delve into the subject at night, and, later on, gave a number of talks on the basic principles involved. When it came time to select a thesis subject he chose one in the field of electron optics. After receiving the Ph.D., Rudy remained at the University to continue his work.

One day in November 1949, Ruth, who was then in the Physics Department at Stanford, rushed into Rudy's lab to tell him that a Sylvania representative was there looking for a man to do research involving electron optics. She found Rudy up to the elbows in lubricating oil, his clothes rumpled and dirty. From the details Ruth had, the opportunity didn't sound particularly interesting to Rudy, but he decided that it wouldn't hurt to talk to the visitor. There wasn't sufficient time to do much more than wipe off the excess oil, but since he wasn't trying to get the job that didn't seem to matter.

The visitor turned out to be a Sylvania vice president and after talking the position over, Rudy was interested. Surprisingly, so was the vice president, who offered him the job in spite of his somewhat shoddy appearance.

Rudy accepted, and they moved to Flushing, New York, where Rudy's talents were applied to television picture tube improvements. At the start all he had was a small office, a pad of paper, a pen, one assistant and an assignment: eliminate defocusing at the edge of the

(*Concluded on page 18*)

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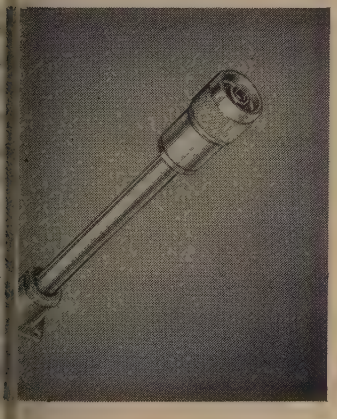
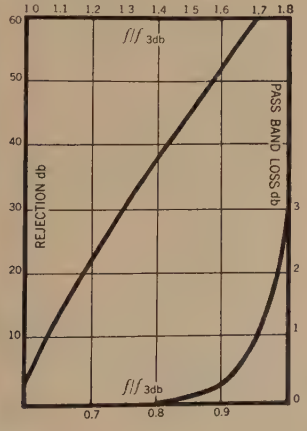
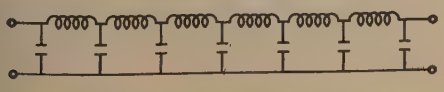




13 ELEMENT NETWORK



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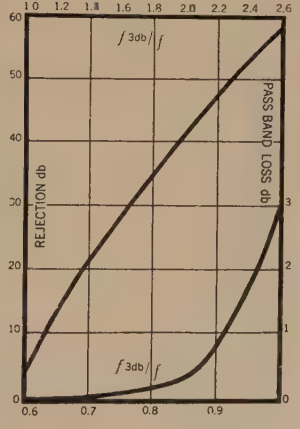
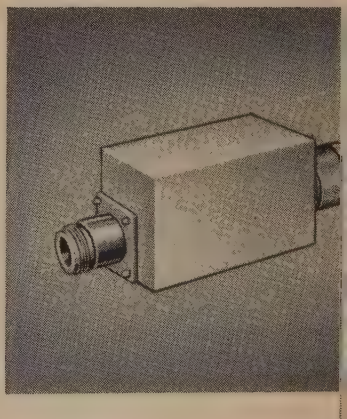
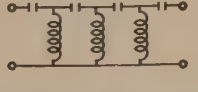




7 ELEMENT NETWORK



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Dr. Hutter

(*Continued from page 16*)

tube. He invented a compensator, and proudly presented it to the picture tube division, only to receive his first rebuff: too costly. In a highly competitive industry, he learned, improvements must add little or nothing to the final cost. At first this came as quite a shock, but a little reflection convinced him of what the marketing experts had learned long before: the public will generally not pay a higher price for an improved product unless the improvement is a major one, revolutionary, or highly dramatic. "Therefore," Rudy was told, "make innovations which will permit the price to remain competitive." This is a mandate which Rudy has never since forgotten.

In 1946, Rudy attended a conference of the IRE group on electron devices, where work on traveling wave tubes was discussed. The subject fired Rudy's imagination, and when, a short time later, Sylvania decided to enter the field, Rudy convinced company management that he was the man to head up the project. Though this was a major move for the company and an important responsibility for Rudy, he remembers 1946 best as the year daughter Barbara was born. Of all the things he has produced, "this," he says, beaming, "is my proudest product." Barbara recently became one of her mother's students at the Castilleja School where Barbara is a sophomore.

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Since 1946, Rudy has played a major role in Sylvania's TWT and backward wave oscillator work. In addition, he has taken part in numerous other projects such as development of the Wamoscope, a microwave display tube which is capable of accepting an RF signal and converting it into a TV or radar picture. Following a series of promotions at Flushing, he was appointed Manager of the company's Physics Research Laboratories at Bayside, New York, and later was moved up to Associate Director there.

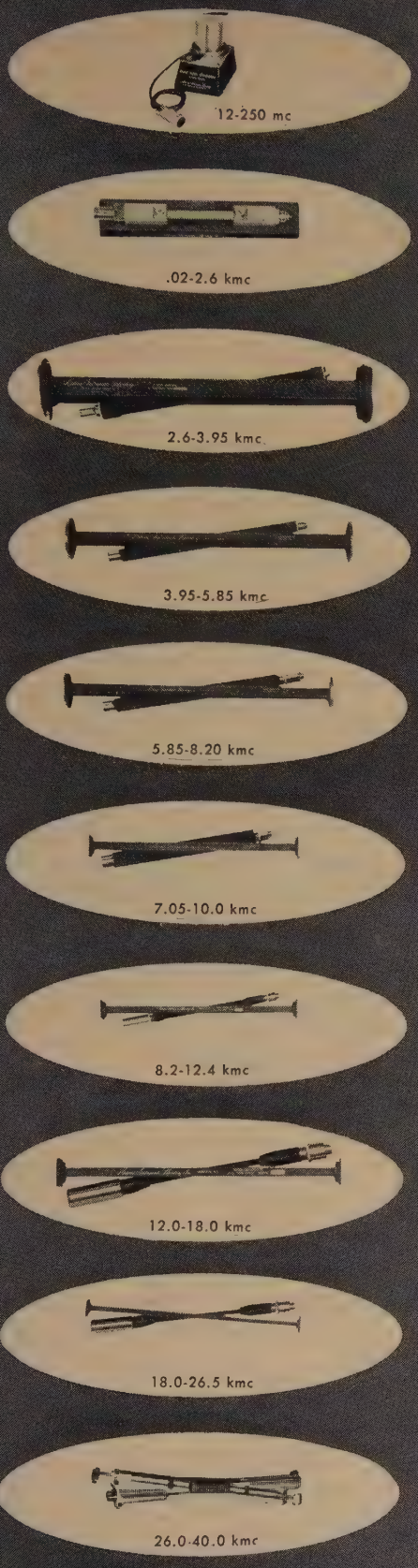
He served as Adjunct Professor of Electrical Engineering at Brooklyn Polytechnic Institute, and during a one-year leave of absence from Sylvania he was visiting McKay Professor of Electrical Engineering at the University of California in Berkeley. In September 1958 Sylvania transferred him to Mountain View, California, where he assumed double duties as Chief Engineer of the company's Special Tube Operations, and Manager of Mountain View Components Laboratories, STO's research, development and engineering arm.

A Fellow of the IRE, and a member of Sigma Xi the Research Society of America and the American Physical Society, Rudy is also a prolific writer: in his twenty years in this country he has authored or co-authored eighteen published papers, and presented many papers to various technical societies. Just published by D. Van Nostrand Company, Inc., is his major effort, a textbook entitled "Beam and Wave Electronics in Microwave Tubes." The new work analyzes the basic physical principles of a wide range of microwave devices from early klystrons to the most recent traveling-wave tubes. Similarities and differences are pointed out by utilizing the coupled-mode theory, space-charge wave theory, and energy exchange. Four chapters on circuitry include an important new treatment of slow-wave guides, discussed in greater detail than has previously been available. Also thoroughly considered are beam and wave electronics in longitudinal and crossed fields, dc to r-f energy conversion, beam and circuit noise, coupling, and noise. Rudy's objective was to make the book useful both as a text and reference for tube designers and as an aid to systems engineers.

Looking back on the last three decades, both Ruth and Rudy realize that once they started dating they entered a period of fear, secrecy and unrest which dominated the years that followed. It was not until they had been in the U.S. for several years — until Rudy had his Ph.D. and a steady job — that they began to achieve a sense of stability and security. And now, as established members of the community, Ruth and Rudy find that they have acquired the feeling of being free and confident Americans.

REPRINTS

Reprints of complete Technical Sections from back numbers of *the microwave journal* are available from the publisher at a cost of 25 cents per back number. Supplies of the following Technical Section reprints are currently out of stock: Vol. 1, No. 1, July/August, 1958; Vol. 1, No. 2, September/October, 1958; Vol. 2, No. 1, January, 1959; Vol. 2, No. 2, February, 1959.



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The AIL Type 70 Series of Noise Generators provide:

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- *Secondary standard of relative excess noise temperature*
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- *Eight waveguide units covering 2.6 to 40 kmc*
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All gas discharge types utilize an argon tube and have an output of 15.28 ±0.25 db.

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Write for complete descriptive literature.

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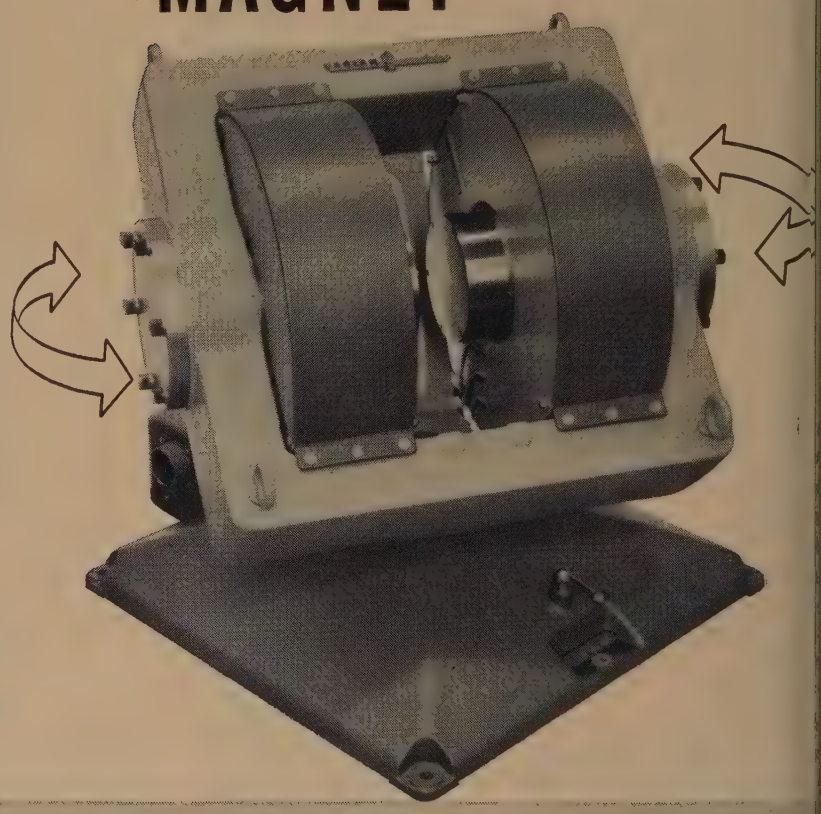
NEWEST FROM VARIAN

A ROTATING 6-INCH LABORATORY MAGNET

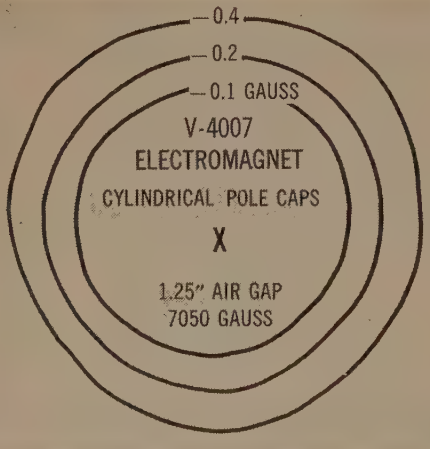
If your research investigations require rotation of a precise magnetic field about the sample under observation, there is now a choice of two Varian laboratory magnets with this capability. A new rotating 6-inch magnet, the V-4007-1, provides a lower-cost alternative to the rotating 12-inch magnet now in world-wide use. The new V-4007-1 is mounted on ball bearings and turns 200° about the vertical axis. Its field is painstakingly aligned by special NMR techniques in the specified air gap.

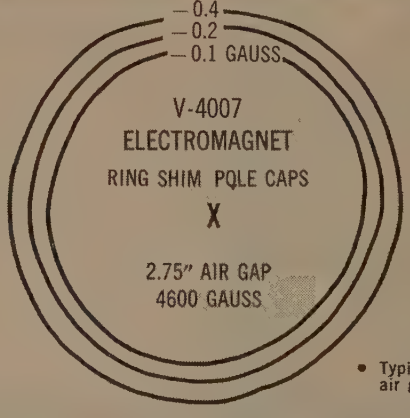
Varian's standard V-4007 fixed-azimuth 6-inch magnet remains in production. It offers continuously adjustable yoke angle, an easily changed air gap, and a somewhat lower cost than the rotating system. Magnetic performance of both 6-inch magnets is essentially the same. In rotating magnets, choice between Varian's 6-inch and 12-inch models is determined by volume, strength and homogeneity of field that your applications require.



Features of the Varian V-4007-1 6-inch rotating magnet

- Rotation of 200° about vertical axis; precisely calibrated scale.
- Yoke fixed at 45° angle.
- Fixed poles, air gap adjustable by changing pole caps; standard-cylindrical, ring-shim-cylindrical and tapered pole caps available on customer choice.
- Maximum air gap:
  4 inches (pole caps of minimum thickness);
  6 inches (pole caps removed)





• Typical full-scale homogeneity plots in median plane of air gap.

Write for specifications on the new Varian V-4007-1 rotating 6-inch magnet and literature on all models.

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CONFERENCE ON QUANTUM ELECTRONICS*

DR. BENJAMIN LAX

HEAD, SOLID STATE DIVISION
Massachusetts Institute of Technology

LINCOLN LABORATORY
Lexington, Mass.

Associate Editor
the microwave journal

IN A BEAUTIFUL SETTING in the Catskills up on a hill, a distinguished gathering of scientists were assembled to discuss a specialized field of research appropriately called *Quantum Electronics.* The moving spirit behind this conference was Professor Townes of Columbia University, whose significant pioneering contributions in the field of masers is widely recognized. He was assisted by a steering committee representing laboratories from both the East and West coasts, including Dr. Irving Rowe, representing ONR, the sponsors of the conference.

The meeting not only concerned itself with the present state of the art of gas masers, atomic clocks and solid state masers, but projected new and exciting ideas into the future trends in quantum electronics. In particular, encouraging progress was reported in the development of millimeter masers. However, the significant note that characterized some of the lectures concerned itself with a restrained but definite note of optimism that sometimes heralds the advent of a breakthrough. Although the difficulties were outlined and recognized, there was an undercurrent of excitement at the future prospect of realizing infrared and optical masers utilizing strong optical pumping in gases, paramagnetic crystals, and in semiconductors. Several papers dealt with the LASER** (Light Amplification by Stimulated Emission of Radiation), which involves transitions in gases at optical and infrared wavelengths. Others were concerned with the IRASER,** (Infrared Amplification by Stimulated Emission of Radiation), using discreet or quasidiscreet levels in solids. The former is further along than the others. Perhaps history will repeat itself, and as with masers, this device which exploits well known spectroscopic transitions in gases will be the first to succeed. However, the devices utilizing solids are still in the running, but perhaps will require a longer time and more extensive research.

*The conference on Quantum Electronics — Resonance Phenomena was held at Shawanga Lodge, Bloomingburg, New York, September 14-16, 1959.

**Strictly speaking the terms LASER and IRASER may be applied to devices involving either a gas or a solid. The distinction lies in the operating frequencies, as indicated by their definitions.

Beam Masers

The introductory remarks which were delivered by Professor Townes indicated how spectroscopy is providing basic information for engineers for their design and development of quantum electronics devices. He stressed the important role of resonance phenomena which are involved in a variety of fields in spectroscopy. The opening technical paper of the first session on beam-type masers which followed was given by J. P. Gordon of Bell Telephone Laboratories, who together with Zeiger and Townes were the triumvirate who developed the first operating maser. He reviewed the history of the ammonia maser and discussed the applications of the beam-type maser for high resolution spectroscopy, its role as a time standard, and its use as an amplifier. There were a number of related papers which discussed various aspects of the beam maser. The Columbia group and Professor Shimoda of the University of Tokyo presented results demonstrating the application of the maser technique to high resolution spectroscopy of gases other than ammonia. This is particularly significant in that beam masers at other discreet frequencies are feasible. F. S. Barnes of Colorado Research Corp. considered such a possibility for amplification and generation of millimeters using a Febry-Perot interferometer as the resonant structure. The necessary transitions at 3.4 millimeter and 0.126 millimeter would be provided by a beam of HCN molecules.

Relaxation and Noise in Masers

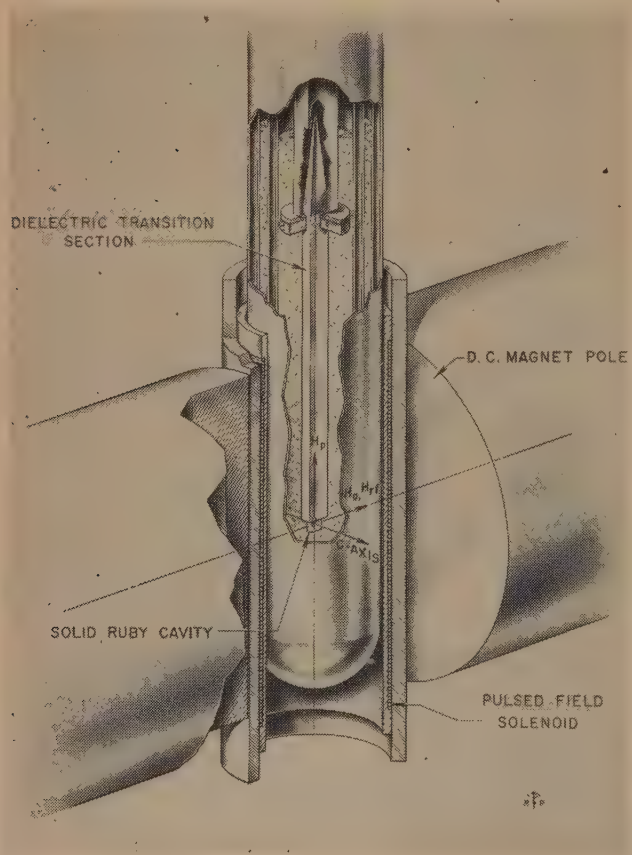
Quite a number of papers dealt with the important problem of relaxation phenomena in solids. Some of these involved nuclear phenomena in ionic and other crystals as well as those in paramagnetic salts. The phenomena of cross relaxation which was postulated by Professor Bloembergen was invoked to explain anomalies of low frequency masers as well as those encountered in paramagnetic resonance at low temperatures. A group from IBM discussed the cross relaxation in connection with maser pumping by a 4-spin flip mechanism. Two spins flipping downward in energy while two spins make an upward transition in a complex double resonance experiment. An analogous phenomenon of cross relaxation and maser action was discussed by F. R. Nash and E. Rosenwasser of Columbia in which a unique situation was found so that a maser could operate at an emission frequency higher than that of the pump.

Other effects which were of practical significance were presented by T. H. Lyman who treated the effects of temperature and concentration of paramagnetic ion concentration on maser performance using a ruby filled cavity. Maser action was achieved and studied in a temperature range from 4°K to 195°K. The concentration effects again demonstrated the exhibition of the cross relaxation phenomena. Similar experiments were also discussed by J. C. Gill of the Royal Radar Establishment who also mentioned the operation of a ruby maser at 77°K by his laboratory.

Various theoretical aspects of the solid state masers were also considered in the conference. The question of noise received a fair amount of attention. Senitsky of the Signal Corps discussed the analysis of noise from in coherent pumping in a three-level system; P. N. Butche of the Royal Radar Establishment also considered th theory of noise and absorption spectra in such a maser E. J. Jaynes of Stanford presented a very interesting ap proach to the maser problem by taking the quantum mechanical theory of the maser and transforming i into a mathematical equation which had a close resemb lance to the equations covering parametric amplifiers thereby demonstrating the similarity between the two.

Another relaxation phenomenon which received a goo deal of attention was the spin lattice relaxation. Th classical results by non-resonant techniques, which were originated in Leiden, were appropriately presented b B. Bölger. He pointed out how these experiments which have been carried out on a large variety of paramagneti salts can be utilized to determine at which temperatur maser action may be expected in a salt. W. S. C. Chan of Stanford University found some interesting result from the use of a traveling wave maser for studying re laxation phenomena in ruby. He discovered that th relaxation time, an important parameter in maser ac tion, is considerably reduced when the frequency of an other transition is a harmonic type or three times that o the one under consideration. This general topic of grea pertinence to the conference was further extended b other contributions from Westinghouse and from Har vard, and was concluded in the evening by a genera discussion led by Professor Van Vleck who reviewed th history of this classical subject, which is still very muc alive and still not fully resolved.

Figure 1 — Sketch of the pulsed millimeter maser developed by Foner, Momo, Mayer and Myers of Lincoln Laboratory.



Microwave and Millimeter Masers

Problems of more practical interest to engineers and applied physicists whose primary goal is the develop ment of masers were presented by Professor Strandberg of M. I. T. who discussed the logical design of paramag netic amplifiers, both the regenerative cavity type and the traveling wave type. He gave a convincing argumen which showed that a cascade of cavity amplifiers can be shown to have gain band width, gain stability and non reciprocal properties essentially equivalent to those of a traveling wave amplifier. A. E. Siegman of Stanford re viewed some of the recent developments of traveling wave masers. He pointed out the advantages of high gain and bandwidth and also its potential as a tool fo microwave magnetic resonance measurements. Othe practical developments which were rather exciting were those given by Hughes Aircraft and Lincoln Laboratory on pulsed solid state masers. The former cited success ful results of maser amplifiers and oscillators at 28 kilo megacycles using ruby and magnetic fields of 18,000 oersteds and with rise times of 400 microseconds. S Foner of Lincoln Laboratory reviewed some results of multi-level pulsed field ruby maser with fields up to 3 kilogauss in which frequencies up to 75 kilomegacycle were obtained. A sketch of the millimeter maser i shown in Fig. 1. This represents the beginning of milli meter masers.

Parametric and Ferromagnetic Devices

Devices which involve resonance phenomena mor

(*Continued on page 24*)

EIMAC CERAMIC-METAL REFLEX KLYSTRONS FOR SEVERE ENVIRONMENT APPLICATIONS

In modern airborne and missile systems, reflex klystrons must be capable of maintaining exceptional frequency stability under conditions of severe shock, vibration and acceleration. Eimac's new ruggedized X- and K-Band reflex klystrons achieve this stability through an advanced system of stacked-ceramic construction and integral brazed 'dual-cavity' design.

Ceramic construction permits internal electrodes to be supported on rigid concentric cones and allows the entire vacuum assembly to be furnace-brazed into a single rugged structure. The resonant cavity design consists of a fixed-tuned (and hence rugged) inner cavity closely coupled through a ceramic window to a secondary tunable cavity outside the vacuum envelope. The external cavity is tuned by means of a capacitive slug over a minimum range of 700 megacycles per tube.

This advanced design has resulted in a series of four exceptionally stable reflex klystrons covering the 8500 to 11,500 megacycle range at a typical output power level of 75 milliwatts. At vibration levels of 15 to 20G the peak-to-peak deviation of these tubes is less than 50 kilocycles for any vibrating frequency from 20 to 2000 cycles per second, with the force applied in any plane of the tube. The advantage of this low FM noise level in local oscillator service is obvious. Ceramic construction and the superior tube manufacturing techniques it makes possible permit tube or seal temperatures of 250°C without impairment of operation.

For severe environment microwave applications investigate the advantages of Eimac ceramic-metal reflex klystrons.

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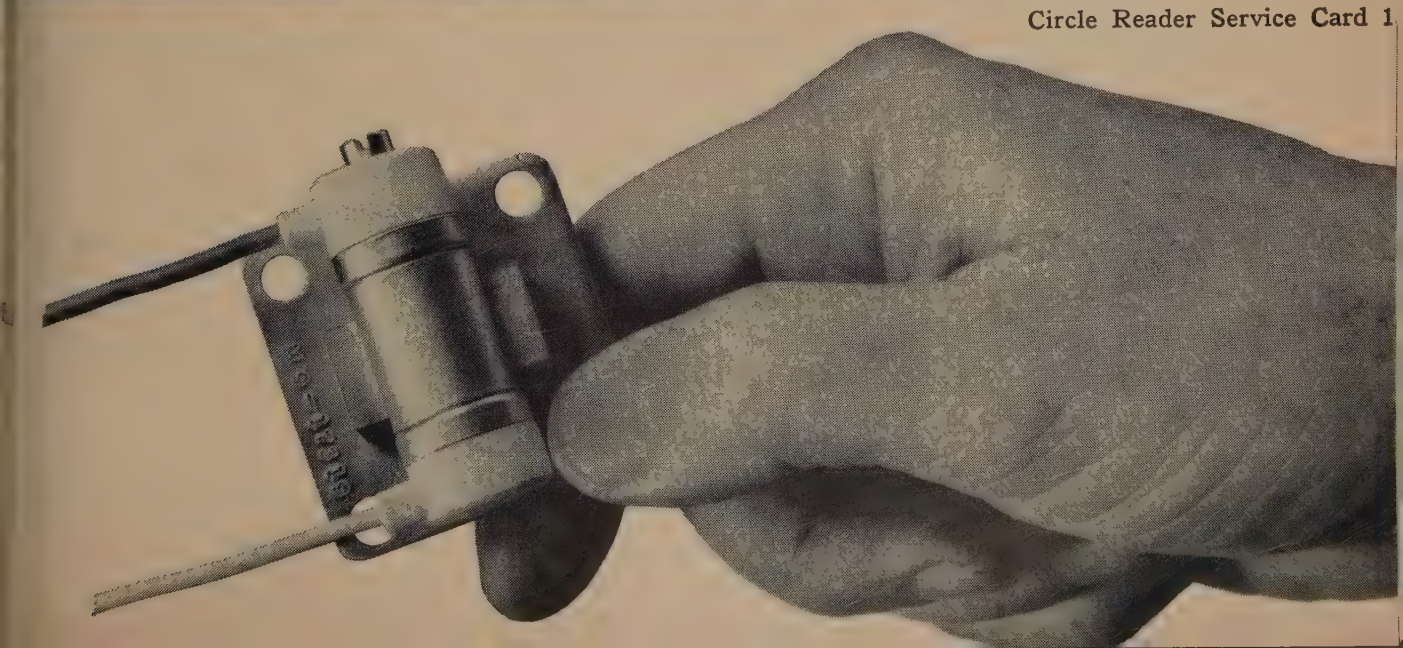


(*Continued from page 22*)

familiar to engineers were reviewed by H. Heffner of Stanford and A. G. Fox of Bell Telephone Laboratories. Professor Heffner considered the various types of parametric amplifiers from a circuit point of view. He compared the advantages and disadvantages of the diode type, the ferromagnetic type with those of a maser. Diodes have been used from one to 10 kmc. Improved noise figure for diodes resulted when these were cooled to liquid air temperatures. Gallium arsenide diodes at low temperatures appear to be the best parametric amplifiers of the degenerative type. He ended with a note of optimism regarding the future of parametric amplifiers for microwave and radio frequency applications. Fox on the other hand did not have such encouraging reports about the ferromagnetic resonance amplifiers. Although much progress has been made in the reduction of power required for the pump in such amplifiers, instabilities and losses associated with the excitation of spin waves and acoustic modes in ferrites and garnets still are obstacles in the development of low noise devices. The ray of sunshine in this field is the nonlinear ferrite harmonic generators which were reported by R. W. Roberts of Melabs. Peak powers of 20-50 watts were generated at 2 millimeters on a pulse basis. He also reported a successful ferrite amplifier with a pump frequency of 9 kmc and a signal frequency of 7.2 kmc with a net gain of 45 db and a pump power of 5 kw.

Optical Pumping and Optical Masers

Topics of current interest which evoked a good deal of attention were those involving the possibilities of optical and infrared masers. An introductory paper by A. L. Schawlow covered the proposal which he, together with Professor Townes made for the use of sodium and atomic potassium vapor for developing such infrared and optical masers. He indicated that milliwatts of power from a potassium lamp in the optical region would be sufficient as a source for such a device. The resonance system would be a Fabry-Perot interferometer in which gold or silver, of 98 percent reflectivity, coated on a dielectric would be employed. He also mentioned the possibility of solid optical masers in which crystals with sharp emission lines and broad absorption bands would be useful in such devices, and in which the ends of rod of such material could be readily silvered to provide a convenient interferometer. He pointed out the significance of achieving a coherent monochromatic optical source, not only as an extremely useful tool for spectroscopy, but also the importance of the directional properties of a plane wave which could be focussed to a spot one wavelength in size to give extremely large electric fields at a point.

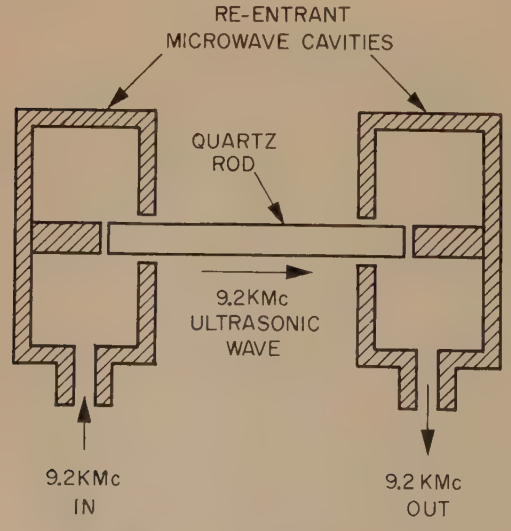
A variation for providing energy for optical masers was proposed by A. Javan of Bell Telephone Laboratory who considered the possibility of obtaining negative temperatures of atoms by electron impact. He proposed to use an electron gun or an avalanche discharge for exciting electrons to the desirable energy states in a gas mixture. The phenomenon involved, utilized the transfer of an electron from a gas with a long-lived excited state to another one with a short life, both having comparable energies.

A number of papers closely related to those devoted to optical and infrared masers, both of the gaseous and solid type, were presented during the course of the conference. Professor Brossel of the Ecole Normale Superieure, Paris, gave an illuminating discussion of the phenomena of the optical excitation in gases and in solids, much of which had been pioneered by this group under Professor Kastler. He discussed optical pumping of an atom in an identical radiation from another source in which circularly polarized light could be utilized to a good advantage to produce negative temperature. He also showed how the use of a buffer gas could reduce the relaxation between two excited states which relax at the same rate and the polarized light could be utilized for differential pumping necessary for maser action. He indicated that an optically pumped maser with sodium vapor would be marginal at low pressures, although the possibility of high pressure operation was perhaps feasible. Optical pumping in solids was also discussed by Brossel who stated the importance of sharp lines in such solids and suggested that these may be achieved by the use of low concentration of ions in salts and the use of low temperatures.

Professor Low of Hebrew University, Israel, presented a review paper on the optical properties of paramagnetic solids. He discussed the basic phenomena of the energy levels of magnetic ions of iron and rare earth groups. The origin of the optical transitions between these levels was outlined in connection with absorption and fluorescence of radiation. He indicated that for optical masers some of the systems may be made operative by exciting electrons to the higher states. These in turn transfer energy to other excited states and populate selectively some of its fine structure resulting in an inverted population necessary for maser action. Optical experiments in ruby along these general lines were already reported by Wieder of Westinghouse. He is utilizing optical radiation from ruby at 6934°A and 6920°A at ~ 0.1 watt level to detect optical pumping in ruby by simultaneous microwave saturation of the lower energy states.

(*Concluded on page 28*)

Figure 2 — Generation and detection of pulsed microwave ultrasonics in a quartz rod.



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NEW RAYTHEON MAGNETRONS FOR A WIDE RANGE OF APPLICATIONS

esigned for C-band systems equiring tunability, the K-7156 magnetron has a min-mum peak power output rat-ng of 250 kilowatts over a requency range of 5,450 to 825 megacycles. Applica-ons include a flight-sted, revolutionary air-rne weather radar system. e RK-7156 is in quantity oduction.

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K-7156

* * *

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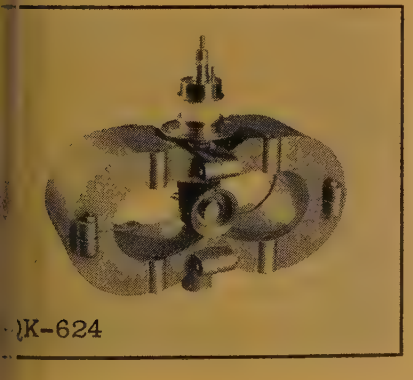

QK-624

power within a frequency range of 9,340 to 9,440 Mc. Designated QK-624, this pulsed-type tube is liquid cooled and should give at least 1,000 hours of reliable service.

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* * *

For ground-based and airborne radar systems, the RK-7529 magnetron provides a 2.0 microsecond pulse of 3.5 megawatts minimum peak power over 2,700 to 2,850 Mc. This liquid-cooled tube is interchangeable with other fixed-frequency S-band tubes operating at similar power levels.

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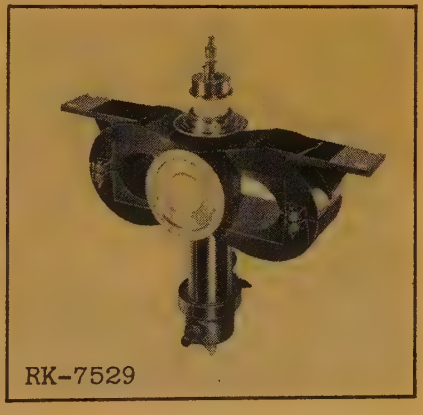
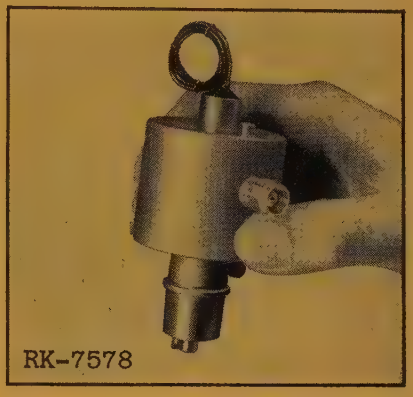


RK-7529

* * *

A one kilowatt beacon magnetron, the RK-7578 weighs only 14 ozs., yet will withstand vibrations of 15 G's at 20 to 2,000 cycles and shock up to 100 G's. It is



RK-7578

mechanically tunable and covers the 5,400 to 5,900 Mc range.

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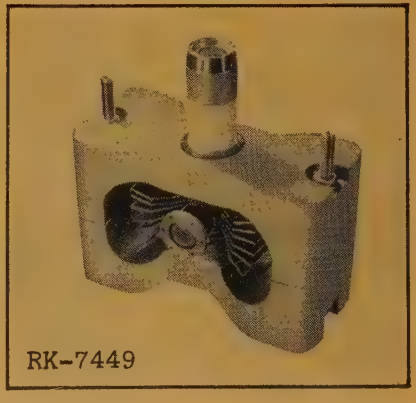
* * *

Developed to withstand extreme environmental conditions, the RK-7449 magnetron is a lightweight, compact tube with a minimum peak power output of 45 kilowatts at the operating frequency of 24 kmc. The RK-7449 is required to withstand re-



RK-7449

peated shocks of 50G. Stable operation is guaranteed at vibration frequencies up to 2,000 c.p.s. with 30G applied.

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Make Possible Simple, More Compact TWT Design

If your line of microwave equipment includes traveling wave tubes, you will be interested in Indiana Steel's amazing ceramic permanent magnets called INDOX.

Unlike heavy Alnico materials, INDOX offers designers of microwave equipment a new, light, inexpensive and easy-to-assemble permanent magnet in the sizes, shapes and strengths necessary for today's critical applications.

For example, in periodic focusing traveling wave tubes, INDOX can supply a much higher flux density due to its higher intrinsic coercive force. And INDOX pieces may also be magnetized prior to assembly without appreciable loss of flux density.

Not only does INDOX open new doors of design, but Indiana Steel now offers two grades of INDOX to meet special microwave design problems—INDOX I and INDOX VI.

INDOX I

In addition to having a higher intrinsic coercive force than Alnico, INDOX I is an inexpensive material manufactured to design specifications at moderate die cost. Irreversible flux density losses do not occur until very low operating temperatures are reached. And INDOX I produces a greater flux density than many other materials when operating low on the demagnetization curve. (See curve below.)

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Through extensive research in Indiana's R&D laboratories, a new, more powerful INDOX material has now been released for use in microwave equipment, particularly the TWT's. Having a greater energy product, INDOX VI can be used when a greater flux density is required or when a smaller magnet must be used.

AVAILABLE FROM STOCK NOW!

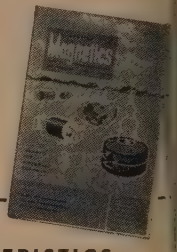
Many unground sizes of INDOX and VI magnets are now in stock. If required, magnets may be ground to closer tolerance prior to assembly. Magnets may be magnetized before or after shipment, as desired.

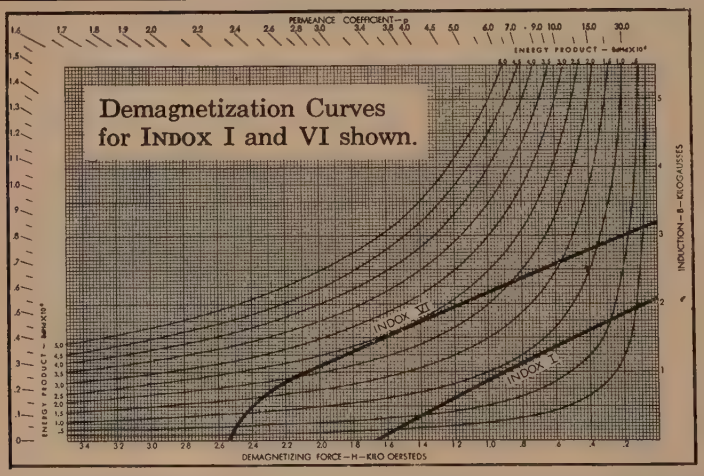
DESIGN ENGINEERING NOTE:

Indiana manufactures the widest selection of permanent magnet materials, available in thousands of sizes and shapes. Therefore, you can depend upon Indiana to give unbiased advice in choosing the correct magnet material for your application.

What are your permanent magnet requirements in the broad-band microwave field? It's likely an experienced Indiana application engineer can help you, so write for full information. Request Bulletin 18Q2 (INDOX I and V) and Bulletin 353Q (INDOX VI).

NEW! *Recently published data on predicting effect of low temperature on* INDOX V *and* VI, *compiled by Indiana scientists. For your copy, write for Applied Magnetics, Fourth Quarter, 1959.*





TYPICAL CHARACTERISTICS

	INDOX I	INDOX VI
Coercive Force (H_c) oersteds	1,825	2,550
Residual Induction (B_r) gausses	2,200	3,200
Peak Energy Product (B_dH_d)	1.0×10^6	2.4×10^6
Reversible Permeability	1.2	1.06
Temperature Coefficient	—0.19%/°C	—0.19%/°C
Magnetization Field for Saturation, oersteds	10,000	10,000
Chemical Composition	$BaFe_{12}O_{19}$	$BaFe_{12}O_{19}$
Specific Gravity	4.7 or 0.17 lb/cu in	4.5 or 0.162 lb/cu in

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INDIANA PERMANENT MAGNETS

SMALLEST LIGHTEST CARCINOTRONS

with wide band sole tuning

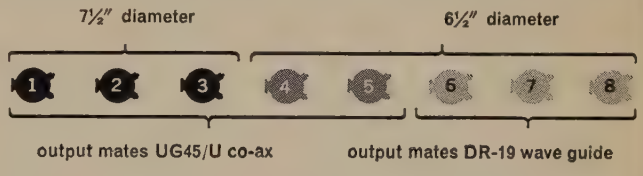
Though it has just recently made its debut into the high society of Litton microwave tubes, this carcinotron (our model L-3298) has already been commended by the military for its exceptionally clean design. Every engineer concerned with upgrading the performance of ECM equipment will surely find much of interest in this medium-power tube, with which Litton takes a major stride toward truly simultaneous noise-jamming capability by affording faster tuning rates than any previously attainable.

The Litton family of eight electrically-compatible carcinotrons is the first to incorporate the critical capability of wide band sole tuning without frequency or power holes when the tube is operated into as much as a 1.5-to-1 mismatch. Litton carcinotrons are the first to use wider-than-normal-band RF output couplers, minimizing many system components such as antennae, waveguide plumbing, and load isolators.

We cite these firsts not for glory's sake, but rather for their meaningful contribution to more efficient system design, smaller size and lighter weight.

The notable suitability of these carcinotrons is not limited to ECM. You can also consider them for other military applications such as drivers for communications links—in fact, wherever medium-power tubes with extremely rapid tuning and low tuning power are required.

Because of their mechanical and electrical compatibility the eight tubes in the family are interchangeable, as shown.



These versatile tubes are not just drawingboard products—you can order them now.

Write concerning voltage-tuned power oscillators of whatever nature to Litton Industries, Electron Tube Division, Office M8, 960 Industrial Road, San Carlos, California. Your request for our Carcinotron Catalog or for answers to your specific questions will be honored promptly.

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LITTON INDUSTRIES Electron Tube Division

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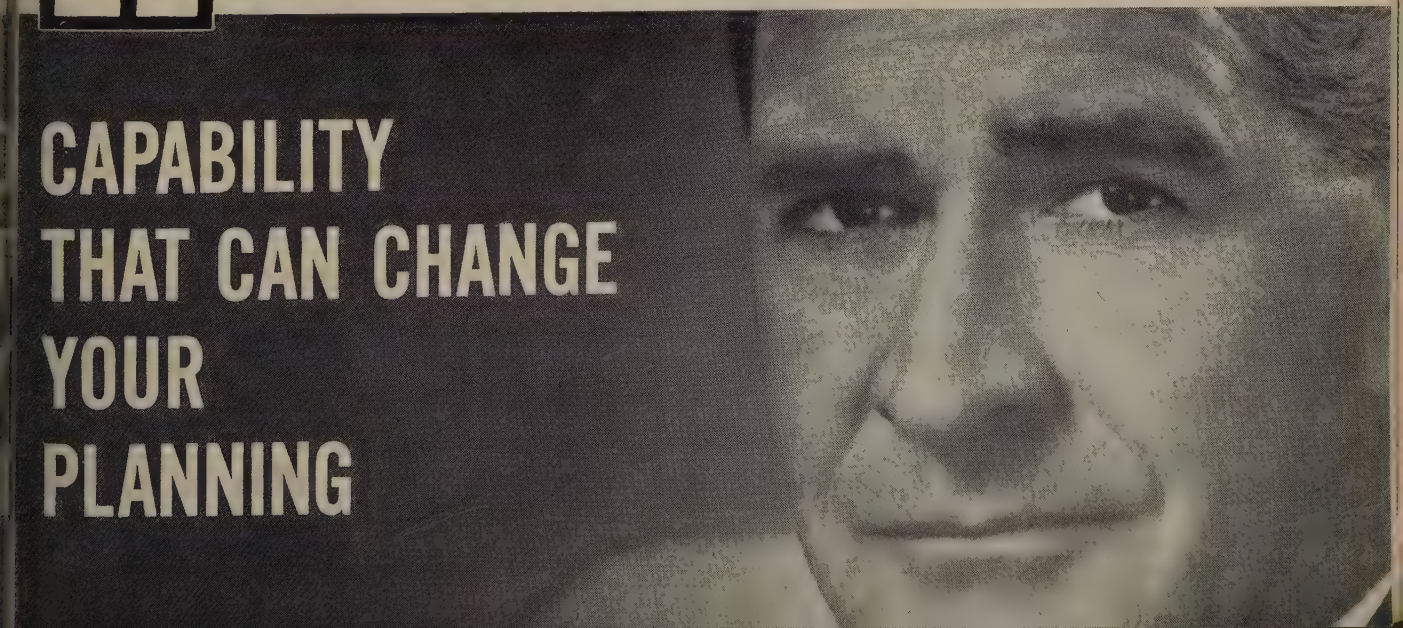
CAPABILITY THAT CAN CHANGE YOUR PLANNING



Quantum Electronics Conference

(*Continued from page 24*)

Optical effects in other solids were discussed by J. Lambe and J. Baker of Michigan, and R. S. Title of I. B. M. The former performed spin resonance experiments on F-centers at low temperatures. Strong optical absorption in KCl crystals with long spin-lattice relaxation produced a 50 percent reduction of the spin resonance signal. Title reported on paramagnetic resonance observations of optically excited infrared stimulable phosphors. The optically stored energy is released by irradiation with infrared and orange light. The reduction of paramagnetic absorption of Eu^{2+} was detected with this type of irradiation.

Semiconducting and Cyclotron Resonance Masers

Another area which is receiving a great deal of consideration at this time was discussed by B. Lax of Lincoln Laboratory. He considered the fundamental phenomena involved in developing semiconducting masers. The two classes of phenomena which were considered were cyclotron resonance and impurity levels. The former is quite attractive from the viewpoint that it allows a wide variety of possibilities from the microwave well into the infrared region. Furthermore, tunability by the use of magnetic fields over a wide range can be achieved. Although at the moment the feasibility of such devices appear marginal, he was optimistic about the eventual development of semiconducting masers. In particular, cyclotron resonance masers look promising. This stems partially from the work of G. C. Dousmanis and coworkers at R. C. A. who presented experimental evidence for emission at microwave frequencies in germanium. They exploited cyclotron resonance associated with the negative mass phenomena of holes in germanium. This has not resulted in a maser and the eventual cyclotron resonance device may take an entirely different form. Nevertheless, the results of the R.C.A. group indicates that this avenue may be a fruitful one. More basic measurements and the investigation of new materials appears to be the key in this direction.

Lax also discussed the properties of impurity levels in semiconductors which may be utilized for emission of energy at microwave, millimeter and infrared frequencies. The complex structure of electron spin resonance in germanium which has been discovered by the group at Lincoln Laboratory, together with the observation of such spin resonance by Feher and coworkers of Bell Telephone Laboratories presents interesting possibilities for microwave semiconducting masers in this material. Spin resonance in silicon which is an older story was also considered by Professor Honig of Syracuse. However, his approach was entirely new since he was studying the resonance under the simultaneous influence of infrared radiation which excited the electrons from the impurities to the conduction band. This produced interesting relaxation phenomena and interactions between bound electrons and electrons in the conduction band.

Microwave Ultrasonics

A number of novel and intriguing techniques were presented during the course of the conference. One of these which aroused a considerable interest was a paper by E. H. Jacobsen of General Electric who discussed ultrasonic techniques at microwave frequencies. He described a method of coupling a microwave pulse into a quartz rod in one microwave cavity as shown in Fig. 2 which then transmitted the energy into another re-entrant microwave cavity similarly coupled to the quartz rod. The coupling mechanism is a piezoelectric phenomenon in which the polished ends of the quartz rod interact with the electromagnetic field at the re-entrant portions of the cavity to act as transducers. The system has been used to study electron spin resonance in quartz at 9.2 kmc.

Professor Lamb from Oxford University, whose fundamental measurement of the Lamb shift by microwave techniques earned him a Nobel prize, presented a paper on the possible use of highly monochromatic gamma rays for microwave spectroscopy. This is possible due to the narrow line width of some gamma rays from solids which are of the order of 5×10^{-11} of its frequency.

A third item of unique interest was a nuclear "maser" magnetometer described by Combrisson of the Centre d'Etudes Nucleaires de Saclay, France. The device took advantage of the Overhauser effect which is the interaction between protons and electrons, but in this case

(*Concluded on page 30*)

Figure 3 — Steering Committee of the Quantum Electronics Conference. Clockwise around the table: N. Bloembergen (Harvard); B. Lax (Lincoln Laboratory); R. H. Dicke (Princeton); A. E. Siegman (Stanford); R. W. Siegel (Columbia); I. Rowe (ONR); G. Birnbaum (Hughes Aircraft); R. Kompfner (BTL); C. H. Townes, chairman (Columbia); C. Kittel (U. of Cal.); M. W. P. Strandberg (MIT).

Figure 4 — Some of the speakers enjoying the cuisine at Shawanga Lodge. Sitting left to right, Mrs. Townes; I. Rowe (ONR); J. P. Gordon (BTL); H. Friedberg (Technische Hochschule, Karlsruhe); C. H. Townes (Columbia); Standing, I. R. Pierce (BTL); M. W. P. Strandberg (MIT); A. Prokhorov (Lebedev Institute, Moscow).

For original equipment, direct replacement

NEC tubes with new doped-nickel cathode

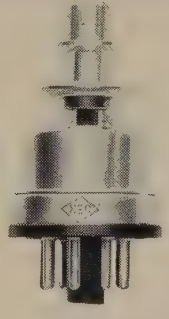
Both tube series described here use NEC's new doped-nickel cathode core material. This 10-year development increases emission without raising operating temperature. Oxide evaporation rate is lower than any known core material. Operating data show tube life is extended up to 50%.

6R-P10

6R-R8

WIDE-BAND AMPLIFIER TUBES: Development began seven years ago with the 6R-R8, which was used in Japan's first microwave link. A modification, 6R-R8C, with very low distortion factor, is used in coaxial amplifiers. 6R-P10 Power Amplifier Pentode, with high mutual conductance and small capacitance, is designed for larger power output.

Type	Name	Cathode Rating		Screen and Plate Supply Voltage Eb (V) Ec2 (V)	Plate Current Ib (mA)	Trans-conductance Gm (μΩ)	Capacitances		Interchangeable Tubes
		Volts Ef (V)	Amp. If (A)				Input μμF	Output μμF	
6R-R8	Sharp-Cutoff Pentode	6.3	0.3	150	13	12,500	7.8	3.2	with WE404A
6R-R8C	Sharp-Cutoff Pentode	6.3	0.3	150	13	12,500	7.3	3.2	with WE404A
6R-P10	Power Amplifier Pentode	6.3	0.5	150	36	13,500	10.5	2.7	——



2C40

2C39B

Type	Use	Cathode Rating		Maximum Plate Voltage Ev (V)	Maximum Plate Dissipation Pp (W)	Power Po (W)	Maximum Frequency f (MC)
		Voltage Ef (V)	Current If (A)				
822	Detector	6.3	0.75	150	——	——	1200
39A	Amplifier Oscillator (Continuous)	6.3	1.0	1000	100	15	2500
2C40	Amplifier Oscillator (Continuous)	6.3	0.75	500	4	0.75	3370
2C43	Amplifier Oscillator (Continuous & Pulse)	6.3	0.9	3500*	12	1.0	3370
961	Amplifier Oscillator (Continuous)	6.3	0.4	350	10	0.5	3700

* Pulse plate Voltage (eb)

DISC-SEALED TRIODES: NEC designed the first disc-sealed tube in 1939, giving NEC many years of experience in the design and manufacture of this type of microwave tube. Each is a direct replacement under all circumstances for the corresponding type. The NEC tube will give longer life, an especially important advantage in repeater stations.

Please write for specifications sheets.

NEC *Nippon Electric Company Ltd.* Tokyo, Japan

COMPONENTS / SYSTEMS

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Quantum Electronics Conference

(*Continued from page 28*)

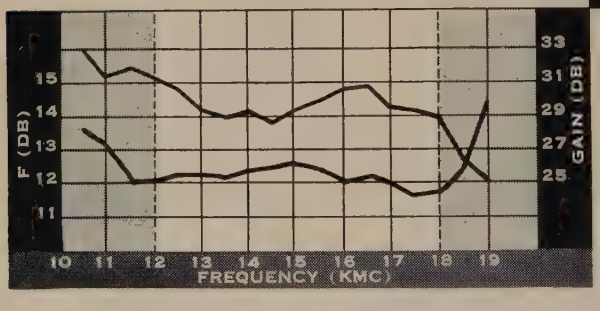
involves those of a free radical in solution, and the protons of the solvent. The enhancement of the interaction provides a magnetometer which is extremely sensitive and can measure changes in the earth's magnetic field of the order of one part in a million.

Several talks of general scientific interest involving the potential use of quantum electronic devices were given by J. R. Pierce of Bell Telephone Laboratories, T. Mathews of California Institute, and Professor R. H. Dicke of Princeton. Pierce considered communications problems over long distances of the order of 6,000 miles as to a satellite and the power requirements to transmit a certain amount of information. He showed how the maser can be helpful in reducing the transmitter power for such a system. Mathews discussed reception of signals in connection with radio astronomy and pointed out the antenna requirements for low noise systems with masers. He also emphasized the need for high gain stabilities for the low noise devices of the order 0.01 percent for such measurements as the hydrogen line. Finally Dicke considered the possibility of using ammonia masers and atomic clocks for the investigation of some cosmological phenomena. In particular he was concerned with the determination of the gravitational and fine structure constants.

The impression that the author received from attending the conference was that quantum electronics was fast becoming a vital and fruitful field of research. The various aspects of this endeavor will undoubtedly give a significant impetus to existing research programs in solid state, spectroscopy, radar, communications and radio astronomy. There seems to be little doubt in the minds of the principals in this field that it is only a question of time that an optical maser will become a reality. Indeed it appears that many of the different approaches should provide results eventually. The use of optical pumping in paramagnetic and semiconducting materials, if successful, will ultimately lead to masers with tuning capability in the millimeter and far infrared regions of the spectrum. The one sentiment which all the participants echoed was that a good deal of basic measurements and development of new techniques will be necessary before any of these devices become operative even in the laboratory.

Figure 5 — Participants of the Quantum Electronics Conference and some of the wives and children.

Actual test data proves the
Broader Band Operation
of this **HUGGINS TWT**



Test graph of our HA 43, medium noise amplifier tube illustrates how Huggins tubes often perform even better than advertised specifications. Huggins equipment consistently "gives the customer more."

Maximum noise figure here is 12.6 DB for 12-18 KMC and 14.3 for 10.5-19 KMC. Both are well below the catalog maximum of 15 DB. A 25 DB minimum gain is present for an **8½ KMC** bandwidth, with greater than 28 DB in the catalog frequencies.
Write us for further information on Huggins TWT's, the industry's most complete line.

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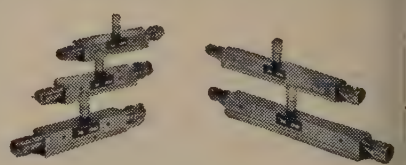
ZERO INSERTION LOSS COAXIAL ATTENUATORS



FEATURES:
0.5 db max. insertion loss
attenuation vs. frequency, linear, flat, positive, negative, slopes available.

Model	Frequency	Char.	Price
A-7	1 to 7 KMC	Linear	$175.00
A-10	1 to 7 KMC	Linear	215.00
AU-10	.3 to 5 KMC	Special	275.00
AE-6	4 to 7 KMC	Flat	285.00
AF-6	7 to 11 KMC	Flat	285.00

In-line and special variations available. Please write for details.

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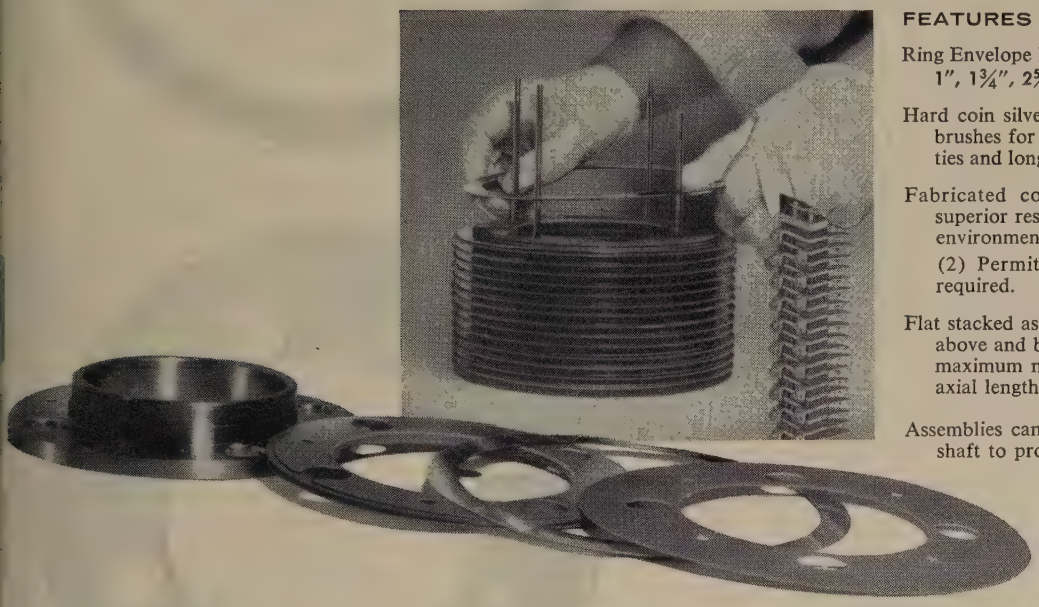
AN ANALYSIS covering over four thousand custom slip ring assemblies designed and produced by Breeze Corporation during the past seventeen years has shown that a substantial number of these requirements have been for assemblies having similar size and operating characteristics.

Now . . . to meet these repetitive requirements more rapidly and at reduced costs, Breeze offers seven standard size slip rings with ring envelope diameters from 1" through 10½".

SEVEN STANDARD SLIP RING SIZES NOW in stock!



FEATURES

Ring Envelope Diameters:
1", 1¾", 2⅝", 4⅞", 9⅜", 10½".

Hard coin silver rings and silver graphite brushes for excellent electrical properties and long life.

Fabricated construction (1) Provides superior resistance to shock, vibration, environmental conditions.
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Flat stacked assembly with rings mounted above and below each barrier provides maximum number of rings in shortest axial length for rated capacities.

Assemblies can be stacked on a common shaft to produce a multiple unit.

You'll want a copy of the new Breeze catalog 66 SR which contains complete details on these standard units. Catalog 66 SR also describes a wide range of custom units and incorporates a design guide section. Write for your copy today.

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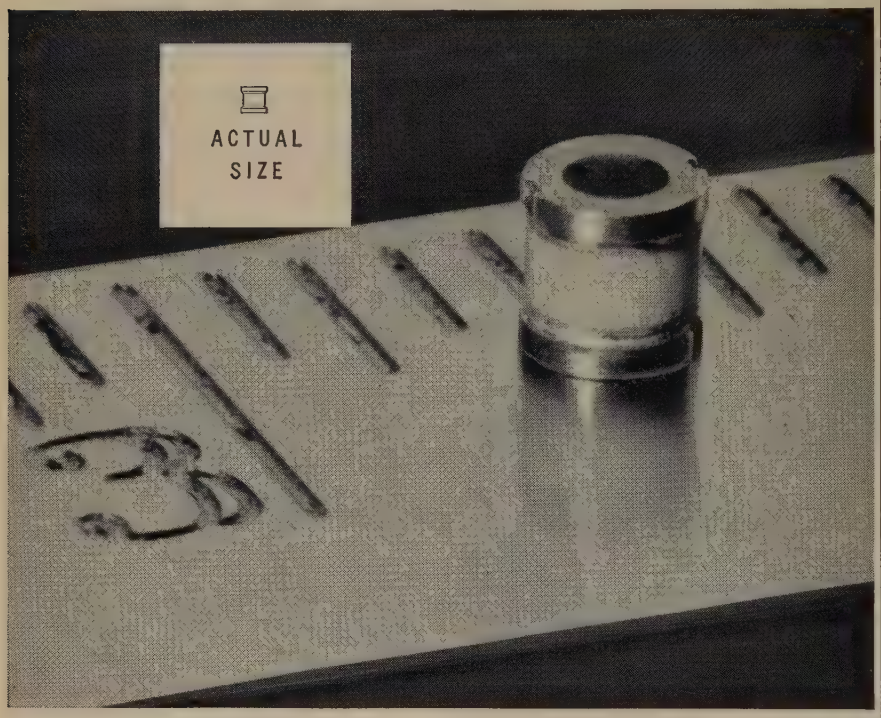

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Experimental quantities are available with these nominal specifications

TYPE NUMBER	*CAPACITANCE TOLERANCE (Zero Bias)	TYPICAL Q AT −6 VOLTS
MA-4255X	0.1-1.4 μμf	60-80
MA-4256X	1.2-2.5 μμf	50
MA-4257X	2.5-4.0 μμf	30

*Package shunt capacitance ~ 0.2 μμf. Series lead inductance $<10^{-9}$ henries.

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INDUSTRY NEWS

FXR APPOINTS KIRSCHNER

Daniel D. Kirschner has been appointed to the newly created position of Director of Industrial Relations by FXR Inc. of Woodside, N.Y. He was formerly sales engineer of microwave test equipment and high-power pulse modulators for the company. His new post is integrated with FXR's plan of broadened organizational activities, found necessary to keep pace with the company's present position in the microwave industry. Mr. Kirschner is charged with the responsibility of maintaining a close liaison between the employees and the company and to act as the company's chief negotiator in the formulation of labor-management contracts.

— *m w j* —

McCULLOUGH JOINS LITTON

John S. McCullough has joined Litton Industries Electron Tube Division, San Carlos, California, as assistant to the general manager. He will be responsible for new product planning, according to Dr. Norman H. Moore, Litton vice president and division general manager.

Previously director of research and engineering of Eitel-McCullough, Inc., Mr. McCullough attended the University of California and Harvard University.

— *mwj* —

SIERRA ANNOUNCES TWO APPOINTMENTS

H. D. Farnsworth

Sierra Electronic Corporation, a division of Philco Corporation, has announced the appointment of H. D. Farnsworth as manager of product planning and Sanford K. Ashby as sales engineer.

Mr. Farnsworth was formerly with Stromberg-Carlson Company in Los Angeles, where he was manager of field services for the company's digimatic numerical control systems. Prior to joining Stromberg-Carlson in 1957, he was associated for ten years with Philco Corporation in various engineering supervisory capacities. His experience also includes six years with the Ford Motor Company.

In his new position with Sierra, Mr. Farnsworth will coordinate the development of new additions to the company's commercial product line. Sierra products include a broad range of communications test and power measurement equipment, as well as custom test equipment and telemetry systems.

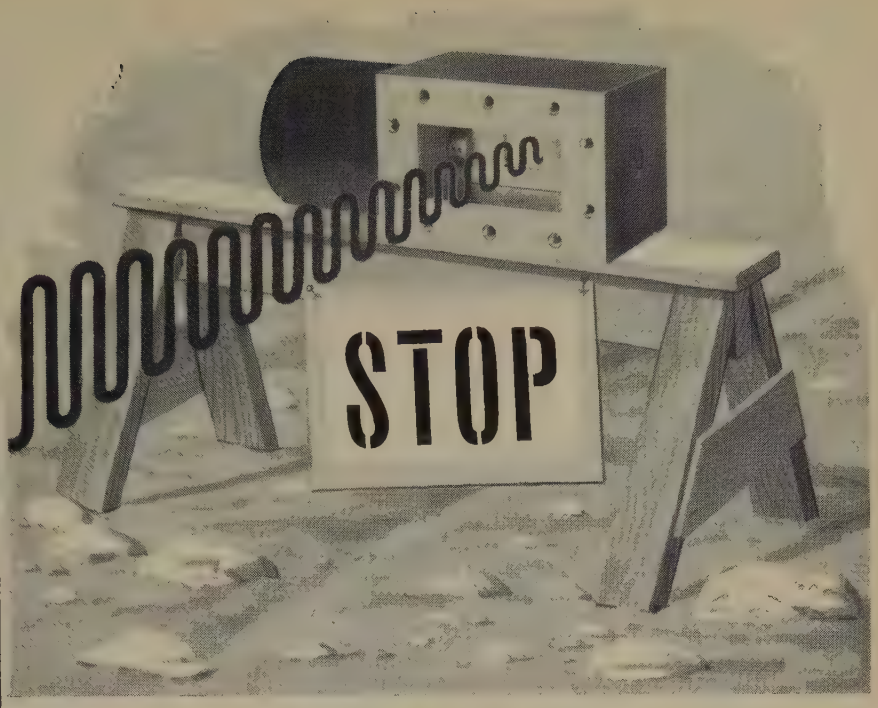
Mr. Ashby, Sierra's new sales engineer, was formerly a partner in Ashby Associates, manufacturers representatives in Dayton, Ohio. Prior to that he was a field engineer for Philco's TechRep Division. A native of Kentucky, Mr. Ashby attended Pratt Institute, Brooklyn, New York, and the University of California.

— *mwj* —

MERRIMAC RESEARCH AND DEVELOPMENT, INC. ANNOUNCES EXPANSION AND NEW PLANT LOCATION

Merrimac Research and Development Inc., formerly in Belleville, New Jersey, have moved to a new plant and laboratory location at 517 Lyons Avenue, Irvington, New Jersey.

(*Continued on page 56*)



DEAD END FOR STRAY POWER...

New rotary shutter for S-Band extends reliable standby protection to RG 48/U waveguide systems.

Microwave Associates' new MA-788 rotary shutter puts up an effective secondary barrier to high level signals . . . forms an important element in the guaranteed crystal protection offered by Microwave's complete duplexing units.

NOW — SIX SHUTTERS AVAILABLE

Six magnetically operated rotary shutters for S, X, Ku and Ka bands are now in our line and are charted below. They form the best-yet supplementary protection against crystal damage when radar system is inoperative. They may also be used as on-off waveguide switches for low power applications. In the closed position they create a dead end short circuit across the waveguide, reflecting essentially all the incident power.

COMPLETE DUPLEXERS OR SEPARATE SHUTTERS

They're available as separate units supplied to fit your system or as components in complete duplexers carrying *guaranteed crystal protection for life . . . at full rated power and elevated temperatures.*

SPECIFICATIONS

Band	Type	Frequency kMc	Isolation (Closed position)	Insertion Loss (Open position)	VSWR (Open position)
S	MA-788	2.7-3.1 kMc	25 db min.	0.2 db max.	1.10 max.
X	MA-710	8.5-9.6 kMc	30 db min.	0.2 db max.	1.10 max.
X	MA-750*	8.5-9.6 kMc	30 db min.	0.2 db max.	1.10 max.
Ku	MA-760	16.0-17.0 kMc	30 db min.	0.2 db max.	1.10 max.
Ku	MA-776**	16.0-17.0 kMc	75 db min.	0.2 db max.	1.10 max.
Ka	MA-761	33.0-36.0 kMc	28 db min.		

*Dual ** Tandem

Write or call for complete data and prices to:

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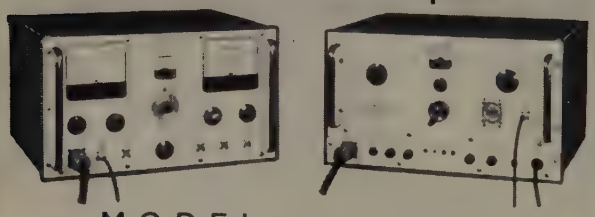
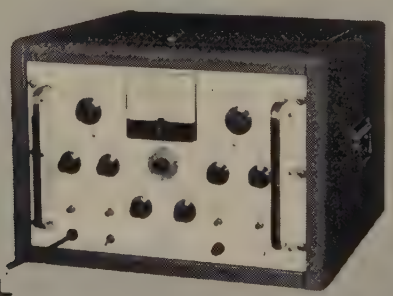
For measurement of microwave and i.f. stability . . .

MODEL 5004
Microwave Stability Tester



MODEL 5009 Microwave Stability Tester
(Indicator plus power supply)

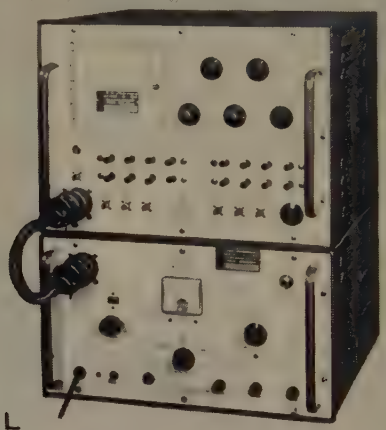
For measurement of pulse jitter in comparator . . .



MODEL 5015 Time Stability Tester

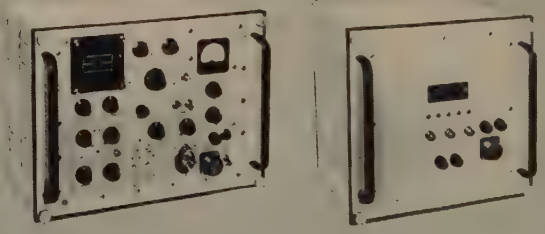
SYSTEM TEST APPROACH

For direct db measurement of overall subclutter visibility at r.f., i.f., video . . .



MODEL 5012 MTI Radar Tester

For measuring System, Receiver and Comparator subclutter visibility in X-band airborne MTI systems . . .



MODEL 5014 MTI Radar Tester/GO-NO-GO Checker
(Indicator plus power supply)

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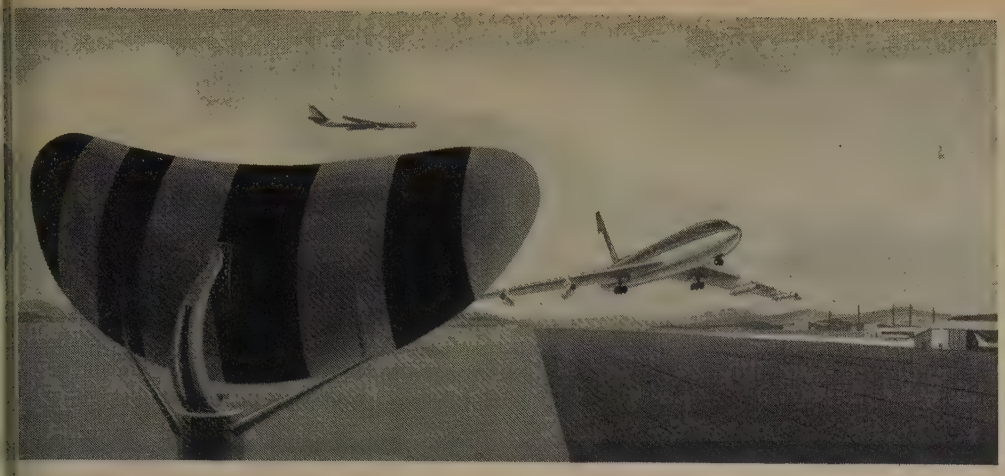

Firm price and delivery on low noise parametric amplifiers

Firm price and delivery schedules are available for negative resistance, cavity type amplifiers in the L, S, C, and Lower X-Bands. You can choose from either development models for evaluation in your system, or custom designed, fully qualified units in production quantities. The table at right shows typical amplifier characteristics now being obtained on development models.

With noise figures as low as 2 db, these amplifiers are ideally suited to radar acquisition and tracking systems, tropo-scatter communications, telemetering, satellite tracking, and microwave relay links.

They recover from overload in milliseconds—are resistant to deterioration and failure from high power. Phase jitter and gain stability characteristics are excellent, and with the associated ferrite circulator, the amplifier is fail-safe in case of pump or diode failure.

Small in size and weight, the amplifier can easily be retrofitted to many existing systems.

Hughes Microwave Products can provide complete retrofit kits, including ferrite circulator, amplifier, pump circuitry, and pump klystron, custom fitted to your system configuration.

HUGHES PARAMETRIC AMPLIFIERS—Typical Characteristics

	L Band	S Band	C Band	X Band
Pump	50 mw at S or C Band	100 mw at X Band	100 mw at X or K_U Band	150 mw at K_U Band
Gain	15 to 20 db	15 to 25 db	15 to 25 db	15 to 20 db
Bandwidth	2 to 10 mc	Up to 25 mc	Up to 25 mc	2 to 8 mc
Noise Figure	2 to 4 db	2 to 4 db	2 to 4 db	6 db
Remarks	Non-degenerate	Non-degenerate	Non-degenerate	Quasi-degenerate

For information on price and delivery dates, or for further technical data, write Microwave Products, Advanced Program Development, Hughes Aircraft Company, Culver City 2, Calif., or phone UPton 0-7111, Ext. 4727.

HUGHES

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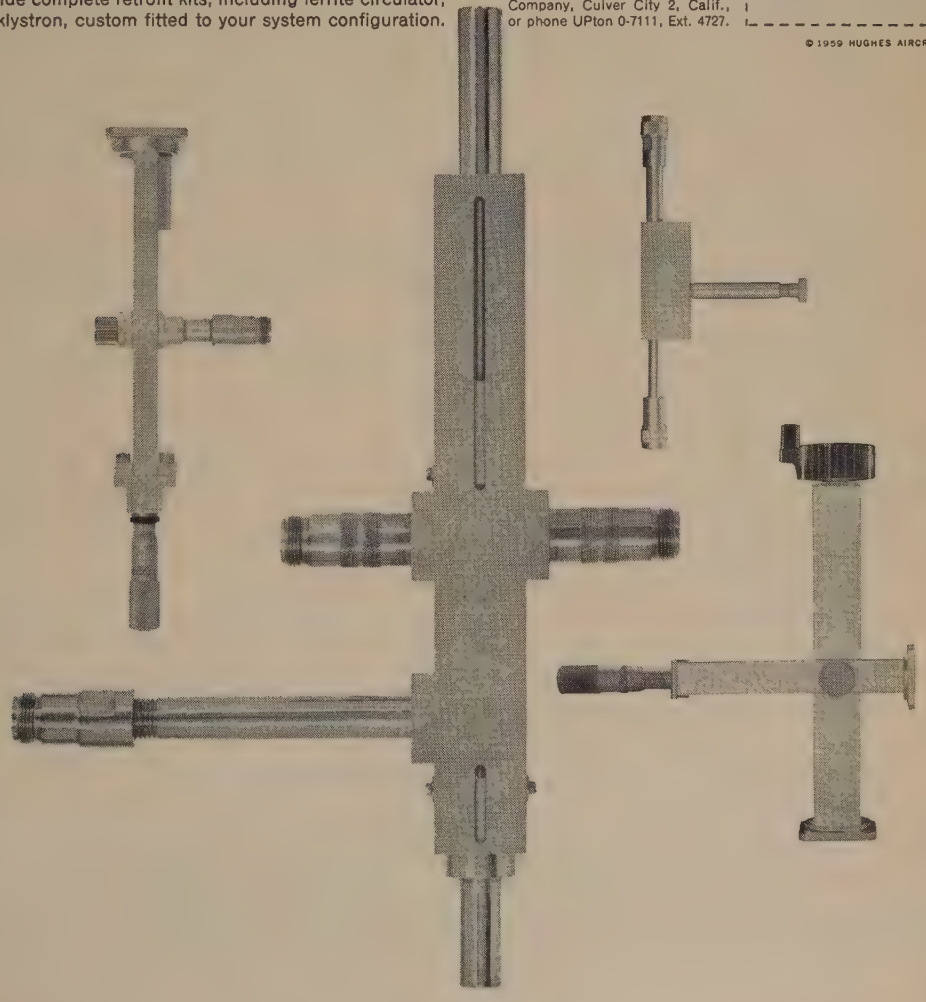

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THOMAS & SKINNER MAGNETS FOR MICROWAVE "PLUMBING"

If you're working on microwave projects, here's a good way to speed the development of your prototypes: Turn your permanent magnet problems over to Thomas & Skinner.

For many years T&S engineers have worked constantly with electronics manufacturers, evolving countless magnet designs to meet critical requirements. No matter how complex the circuit assembly, T&S engineers can help you achieve the best possible compromise as to PM shape, size and strength.

When writing for personal engineering assistance, please include a blueprint or sketch giving dimensions, tolerances, flux density or magnetic force required, magnetization with or without pole pieces, and any unusual operating conditions which might affect the magnet's performance.

Here are some of the T&S magnets available for wave guide applications:

CARCINOTRON MAGNETS
BACKWARD WAVE OSCILLATORS
REFLEX OSCILLATORS
MAGNETRONS
TRAVELING WAVE TUBES
DUPLEXORS

Numerous designs in C magnets are available from stock tooling. Consult Thomas & Skinner for expeditious handling of prototype or production requirements.

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CONTRIBUTORS IN THIS ISSUE

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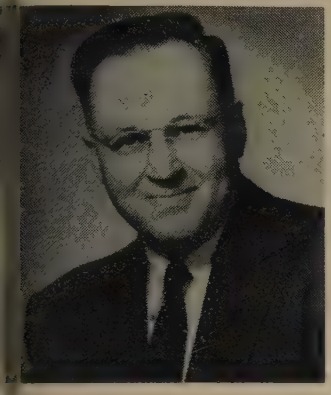


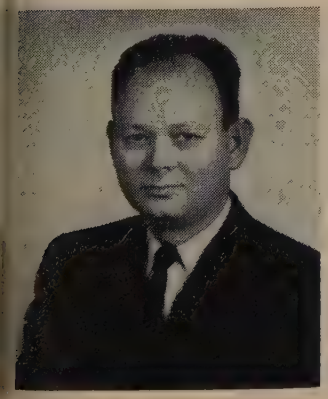
HENRY H. GRIMM obtained an AB degree in Physics in 1935 from Lebanon Valley College, and an MA degree in Physics in 1936 at the University of Pennsylvania. He has since completed the equivalent of two more years of graduate work at the University of Pennsylvania, Pennsylvania State University, and the University of Maryland.

In 1951, Mr. Grimm joined General Electric Electronics Laboratory where he is now a Consultant to the Laboratory in the microwave field.

His past experience includes five years [1946-1951] at the Naval Research Laboratory where did research in microwave propagation in hot gases and supervised the planning of the electronics standards facilities for the Navy's Bureau of Aeronautics. From 1943 to 1946, Mr. Grimm was employed in the Special Projects Laboratory, Wright Air Development Center, where he became supervisor of one branch of the countermeasures laboratory and participated in planning the Air Force program for post-war ECM research and development. Previous to this, he was an instructor for two years in the Physics Department of Pennsylvania State University.

ROBERT D. HALL received his Bachelors' degree in physics from Reed College in 1955 and pursued graduate study at the University of Rochester. After a short tour of Army duty he joined the Sylvania Electronic Defense Laboratory in Mountain View, California as an engineer in 1958. Since that time he has been working on the microwave properties of ferroelectrics, on their microwave circuit applications and related instrumentation. He is a former National Science Fellow and member of KME and the American Physical Society.

As a Senior Engineer at Sylvania, EDL, his work will continue to be devoted to the microwave applications and properties of ferroelectrics and other solid state materials.



SEARCY HOLLIS was born on November 6, 1918 at Collier, Georgia. He received the B.E.E. degree in 1950 and the M.S.E.E. degree in 1956 from the Georgia Institute of Technology.

During the war he was active in the radar field, first as a civilian, and later in the Navy. From 1948 to 1959 he worked in the development of high-speed scanning antennas at the Engineering Experiment Station at Georgia Tech where he was Assistant Head of the Radar Branch. This interval also included experience in underwater sound, meteor scatter propagation, microwave component development, and radar systems design.

From 1954 to 1959 he was a consultant to Scientific-Atlanta, Inc. on antenna measurements techniques. On February 1, 1959 he joined the staff on a full-time basis and is now Vice-President of Engineering.

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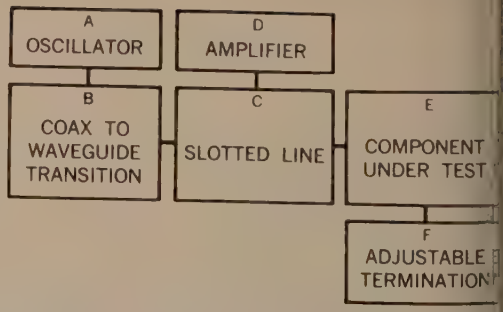

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ANTENNA MEASUREMENTS

J. SEARCY HOLLIS
VICE-PRESIDENT, ENGINEERING
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PART I

troduction

This paper is a review of some of the factors asso- ated with measuring the radiation characteristics of tennas. It is written for the individual who is faced ith the problem of making antenna measurements but hose experience has been largely in other fields of ectronics. It is hoped that some of the material, such the references and nomographs, will be of value also others who have had experience with antennas.

Chapter I is a brief review of basic theory. It is t intended as a complete discussion but as a means defining terms which are employed in the later sec- ons. Proofs are not given for the statements made; stead, references are made to standard antenna texts d periodicals.

Chapter II is a discussion of some practical aspects problems associated with antenna measurements. apter III is a description of equipment, and Chapter IV a review of basic antenna measurements.

The Appendix contains a list of symbols, a bibliog- phy containing all the references of the text, nomo- aphs, and a selection of commonly used antenna uations.

CHAPTER I
THEORY AND BASIC RELATIONS

An antenna may be defined as the structure associated ith the region of transition between a guided wave and free-space wave, or vice versa.[1] The characteristics which describe the properties of an antenna in accomplishing this transition are the *input impedance, the antenna efficiency,* the *radiation pattern,* and the *polarization.*

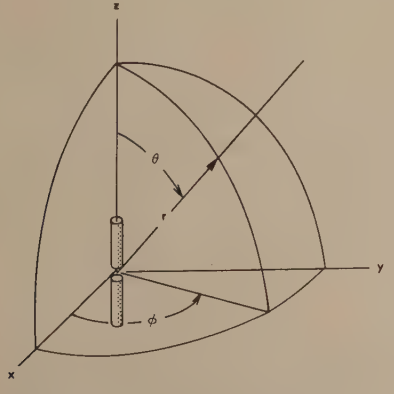

Figure 1 — Spherical coordinate system

The input impedance is the parameter which describes the antenna as a circuit element. It is of primary importance in determining efficiency of transferring power from the source to the antenna and in determining the reaction of the antenna on the source. The antenna efficiency, η, is the ratio of the power radiated into free space to the power input at the antenna terminals. The fraction $1 - \eta$ represents ohmic losses in the antenna. The radiation pattern and polarization describe the radiated electromagnetic field at large distances from the antenna. In this discussion we are interested mainly in the radiation characteristics of the antenna and, therefore, confine our attention largely to the radiation pattern, polarization, and antenna efficiency.

At large distances from a radiating antenna, the electric and magnetic vectors of the radiated field are at right angles to each other and to the direction of propagation. The two fields oscillate in time phase and the ratio of their magnitudes, E/H, is a constant, ζ, which is called the intrinsic impedance of free space and has a value of approximately 120π ohms. The polarization of an electromagnetic field is defined as the direction in space along which the electric vector points, and the polarization of an antenna is described by the polarization[a] of its radiated field.

Radiation Patterns

The radiation patterns of transmitting antennas can be described from two different viewpoints. For low frequency antennas it is convenient to express the radiation pattern as an electric field in space in terms of the input *current* to the antenna and a function called the effective length or field pattern of the antenna. At the higher frequencies where antenna current loses its significance and where the antenna may be described from the viwpoint of physical optics, it is more convenient to define the radiation

[a] In the following sections it is assumed that the electromagnetic field is *linearly polarized;* that is, that the electric vector oscillates in a *line,* which is normal to the direction of propagation. Elliptical polarization is discussed under that heading.

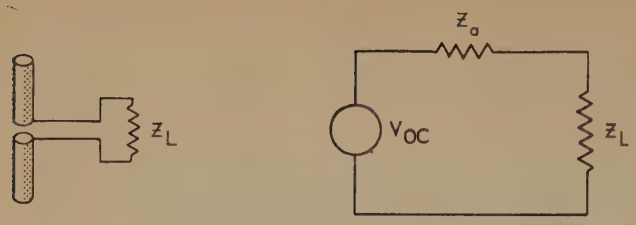

Figure 2 — Receiving antenna and Thevenin equivalent system

pattern in terms of the radiation intensity, the power flow per unit solid angle about the antenna, for a given input *power* to the antenna.

The quantities used to express antenna characteristics from both viewpoints are defined and related below. Because, for convenience, most low frequency antenna measurements are made by scaling to higher frequencies, the power viewpoint will be used in later sections.

Effective Length

The radiation field of an antenna at a large distance r can be expressed in terms of the input current, I_o, and the *effective length*, $h(\theta, \phi)$, of the antenna by the relation

$$E = j\zeta \frac{I_o h(\theta, \phi) e^{-j\beta r}}{2r\lambda}, \tag{1}$$

where β is $2\pi/\lambda$, and $e^{-j\beta r}/r$ describes the variation of amplitude and phase of the radiated wave with distance.[2] The spherical coordinate system involving θ, ϕ, and r is shown in Figure 1.

The effective length of an antenna in a direction (θ, ϕ) is defined [3] as the length of a hypothetical antenna with a constant current I_o along its length which, when oriented normal to the direction θ, ϕ, radiates the same field intensity in the direction θ, ϕ. I_o, as above, is the input current to the actual antenna.

The effective length is seen to be a function of the angular coordinates about the antenna. It is also referred to as the *field pattern* of the antenna.

As can be seen from equation (1), the effective length or field pattern is independent of the distance r. Equation (1) is valid, however, only in the *far zone* of the antenna. The conditions which define the transition into the far zone are

$$\text{(a)} \quad r \gg \lambda \text{ and} \tag{2a}$$

$$\text{(b)} \quad r \geqq 2d^2/\lambda \tag{2b}$$

where d is the maximum dimension of the antenna.[b]

The Reciprocity Theorem

The reciprocity theorem [4] states that the directional pattern of a receiving antenna is identical with its directional pattern as a transmitting antenna.[c] Using this theorem, the effective length, $h(\theta, \phi)$, of an antenna which is defined above on transmitting can be used to determine the current in the antenna load when the antenna is employed on receiving by means of the Thevenin equivalent circuit [5] of the antenna. The Thevenin equivalent circuit for a receiving antenna is shown in Figure 2, where Z_L is the load impedance, Z_a is the impedance looking into the antenna on transmission, and E_i is the component of the incident electric field in the plane of polarization of the receiving antenna.

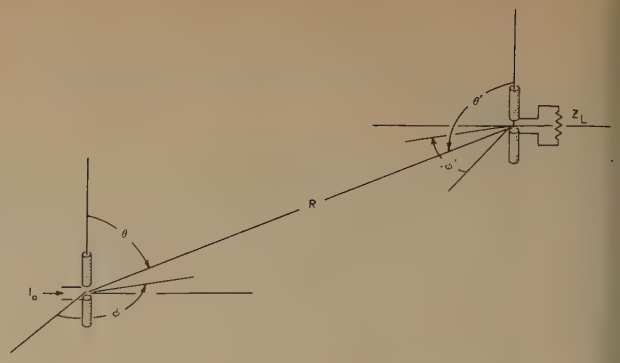

Figure 3 — Geometry for equation (4)

The open circuit voltage, V_{oc}, is given by [6]

$$V_{oc} = E_i h(\theta, \phi). \tag{3}$$

Since Z_a and Z_L are independent of the direction of arrival of the wave, it can be seen that the load current varies directly as the effective length or field pattern $h(\theta, \phi)$.

When a current flows in the terminals of a transmitting antenna, the current which flows in the load impedance Z_L, attached to the terminals of a receiving antenna, can be computed from equations (1) and (3) by means of the circuits shown in Figure 2. The result is

$$I_L = j\frac{60\pi I_o h(\theta, \phi) h'(\theta', \phi') e^{-j\beta R}}{(Z'_a + Z'_L)\lambda R} \cos \alpha \tag{4}$$

The unprimed and primed quantities of Figure 3 refer to the parameters associated with and coordinates about the transmitting and receiving antenna respectively. The factor $\cos \alpha$, is required to take into account the relative plane of polarization of the transmitting and receiving antennas.

The Directivity

As discussed above, it is often convenient to express the directive properties of an antenna in terms of the input power rather than the input current. From this viewpoint the directive properties of an antenna can be expressed by the *directivity*,[7] $d(\theta, \phi)$, which is proportional to $[h(\theta, \phi)]^2$. The directivity is defined as the ratio of the *radiation intensity*,[8] $\Phi(\theta, \phi)$ (the power radiated per unit solid angle in a given direction) to the *average* radiation intensity (the average power radiated from the antenna per unit solid angle).[d] Thus,

$$d(\theta, \phi) = \frac{\Phi(\theta, \phi)}{\Phi_{av}} = \frac{\Phi(\theta, \phi)}{P_t/4\pi} \tag{5}$$

[b] Far zone requirements in antenna measurements are discussed in more detail in Chapter II under *Siting Considerations.*

[c] This discussion applies only to antennas which obey the reciprocity theorem; antennas containing certain ferrite or other uni-lateral devices are thus excluded.

[d] The common unit of solid angle is the steradian; there are 4π steradians in a sphere.

where P_t is the total radiated power, that is, the total power, P_o, into the antenna terminals multiplied by the antenna efficiency, η. The maximum value of the directivity will be called the *maximum directivity.*

It is significant to note that the average value, $\bar{d}$, of the directivity is unity.[e]

The Gain

The *gain,*[9] or power gain, is the product of the directivity times the antenna efficiency, η; that is,

$$g(\theta,\phi) = \eta d(\theta,\phi). \tag{7}$$

The *power density,*[10] $P(\theta,\phi)$, or power flow per unit area of the transmitted wavefront, is given by

$$P(\theta,\phi) = \frac{P_o g(\theta,\phi)}{4\pi r^2}. \tag{8a}$$

Thus also,

$$P(\theta,\phi) = \frac{P_o \eta d(\theta,\phi)}{4\pi r^2} = \frac{P_t\, d(\theta,\phi)}{4\pi r^2}. \tag{8b}$$

The maximum value of the gain will be called the *maximum gain;* the terms *directivity* and *gain* will mean the values of the directivity or gain in any direction (θ,ϕ). The *relative gain* of an antenna is defined as the ratio of the maximum gain of the antenna to that of some standard antenna, often a half-wave dipole. The *absolute gain,* which is synonymous with the *maximum gain* defined above, may be considered the relative gain of the antenna with a lossless *isotropic*[f] antenna as a reference.

Receiving Cross Section

The directive properties of a receiving antenna can be described by the *receiving cross section,* or *effective area,* $A(\theta,\phi)$ of the antenna. The receiving cross section is defined as the ratio of the power $P_r(\theta,\phi)$ received in a matched load attached to the antenna to the power density $P'(\theta,\phi)$ in the incident wave:

$$A(\theta,\phi) = P_r(\theta,\phi)/P(\theta,\phi). \tag{9}$$

[e]

$$\bar{d} = \frac{\int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} d(\theta,\phi)\,\sin\theta\,d\theta\,d\phi}{\int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi}\sin\theta\,d\theta\,d\phi} =$$

$$\frac{\int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi}\Phi(\theta,\phi)\,\sin\theta\,d\theta\,d\phi}{P_t} = 1 \tag{6}$$

[f] An isotropic antenna is a hypothetical antenna which radiates uniformly in all directions.

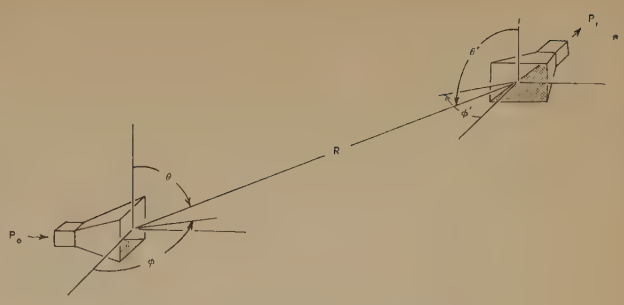

Figure 4 — Geometry for equation (10)

By use of the reciprocity theorem, the receiving cross section is found to be related to the gain by the relation

$$A(\theta,\phi) = \frac{\lambda^2}{4\pi} g(\theta,\phi). \tag{9a}$$

When power is transmitted from one antenna to another which is separated from it by a distance R (Figure 4), the received power can be determined by use of equations (8a) and (9a). Equation (8a), with R substituted for r, gives the power flow per unit area across the *aperture*[g] of the receiving antenna. Equation (9a) gives the total effective area of the receiving antenna normal to the direction (θ,ϕ) through which this power flows. The power received in a matched load attached to the terminals of the receiving antenna is

$$P_r = P_o\left(\frac{\lambda}{4\pi R}\right)^2 g(\theta,\phi)\; g'(\theta',\phi') \cos^2\alpha \tag{10}$$

The unprimed and primed quantities refer to parameters associated with and to coordinates about the transmitting antenna and receiving antenna respectively. The factor, $\cos^2\alpha$, is required to take into account the relative phases of polarization of the transmitting antennas; compare with equation (4).

Elliptical Polarization

The preceding discussion is based on the assumption that the electromagnetic field is linearly polarized. This means that the terminus of the electric vector at a point in space describes a *line* which is normal to the direction of propagation. Most antennas are designed to be linearly polarized. In the general case, however, the terminus of the electric vector at a point in space describes an *ellipse* in a plane which is normal to the direction of propagation. This is called *elliptical polarization.*[11] The *sense* of polarization is defined for an observer watching the *outgoing* wave from behind the source. The polarization is termed *right-handed* if the terminus of the E vector traces the ellipse in the *clockwise sense.*[12]

The elliptically polarized field can be broken into any pair of linearly polarized field components oscillating at right angles to each other. In general, the two components

[g] The aperture of an antenna is a surface through which virtually all of the power that flows into or out of an antenna can be assumed to pass. For convenience, in calculations of the performance of high gain antennas, the surface is usually assumed to be a plane which is located immediately in front of the antenna.

do not have the same phase or amplitude; the total power density in the radiated field is given by the sum of the products of each electric field component with its associated magnetic field component. These pairs of perpendicular electric or magnetic field components are said to be *orthogonal.* The particular pair which are aligned along the major and minor axes of the ellipse are in phase quadrature.

In the special case in which the amplitudes of the two axes of the ellipse are equal, the wave is said to be *circularly polarized.* Any elliptically polarized wave can also be expressed as the sum of a right-handed and a left-handed circular component with properly chosen relative amplitudes and phases. It turns out that the total power density in the wave is the sum of the power densities in the two counter-rotating circularly polarized components, as it is for the two orthogonal linearly polarized components discussed above.[13] These circularly polarized components are also said to be orthogonal.

Although equations (1) and (3) are not applicable to elliptically polarized waves, a more general form of these equations is applicable. For elliptical polarization these more general equations are[14]

$$\vec{E} = j\zeta I_o \vec{h}(\theta,\phi)\frac{e^{-j\beta r}}{2r\lambda} \tag{1a}$$

and

$$V_{oc} = \vec{E}_i \cdot \vec{h}(\theta,\phi), \tag{3a}$$

where the superscribed arrows denote quantities which are space vectors, whose components are generally complex to permit description of the polarization characteristics of the field pattern and the field. A detailed description of the response of an arbitrarily polarized antenna to an arbitrarily polarized wave is given by Sinclair in reference 14, and a general discussion of the polarization properties of antennas is given by several writers[15] in the Proceedings of the IRE. For elliptically polarized waves, any of the power functions appearing in equations (5) through (9) can be expressed as the sum of the corresponding functions for any pair of orthogonal components.[16] Jordan and Bohnert in separate articles define a "total" gain which is the sum of the gains for two orthogonal components. Bohnert gives an expression for calculating the power transfer between two elliptically polarized antennas in terms of the total gains, the axial ratios of the polarization ellipses, and the angle between the major axes of the ellipses. It should be noted in referring to the article by Bohnert that equation (46) contains a misprint and comparison should be made in the equation (43) of the previous article by Kales.

CHAPTER II

PRACTICAL CONSIDERATIONS

This chapter contains discussions of several problems which are of practical interest to the engineer in making antenna measurements. The first topic, on the subject of *decibels,* is of general interest and is required for use of most of the subsequent material; the last four subjects are basic problems encountered in setting up antenna test ranges.

Decibels

The use of *decibels* in calculations and measurements of antenna characteristics is almost essential. The decibel, abbreviated *db,* is a logarithmic unit which is used to measure the *ratio* between two amounts of *power.* By definition,

$$\text{number of db} = 10 \log P_1/P_2, \tag{11}$$

where P_1/P_2 is a *power ratio.* When P_1/P_2 is *greater* than unity, the number of db representing the ratio P_1/P_2 is *positive;* when P_1/P_2 is *less* than unity, the number of db representing P_1/P_2 is *negative.* Where the power ratio is less than unity, the fraction is often inverted and the ratio is expressed as a decibel loss.

Since power, voltage, and current are related by

$$P = V^2/R = I^2R, \tag{12}$$

$$\text{number of db} = 10 \log \frac{(V_1)^2/R_1}{(V_2)^2/R_2} = 10 \log \frac{(I_1)^2R_1}{(I_2)^2R_2}, \tag{13}$$

and, for the important case where $R_1 = R_2$,

$$\text{number of db} = 20 \log \frac{V_1}{V_2} = 20 \log \frac{I_1}{I_2}. \tag{14}$$

The value of the use of decibels in antenna work is largely based on two factors. First, if n_1 and n_2 are power *ratios* whose values in db are N_1 and N_2, the product n_1n_2 is represented by $[N_1 + N_2]$ db, and n_1/n_2 is represented by $[N_1 - N_2]$ db. This permits the handling of products and quotients of large power ratios simply by the operations of addition and subtraction. Second, the decibel scale represents a compression of the power ratio scale, which is extreme for large ratios. This permits the display of tremendous power ratios on a single graph with adequate resolution at all power levels.

To permit use of the decibel in specifying power *levels,* P_2 of equation (11) is sometimes set equal to a specific value of power. The dbm is such a measure which is almost universally used; it is defined with P_2 equal to *one milliwatt:*

$$\text{level of } P_1 \text{ in dbm} = 10 \log P_1/1 \text{ mw}.$$

Often the db is used informally to indicate a power level where the reference is understood. For example, it is customary to express side lobe levels as "—N db" with no reference indicated. This is understood to mean "at a level of —N db with reference to the maximum level of the main lobe."

Signal Levels and Dynamic Range

The power from a transmitting antenna received at the terminals of a receiving antenna is given by equation (10), Chapter I,

$$P_r = P_o\left(\frac{\lambda}{4\pi R}\right)^2 g(\theta,\phi)\, g'(\theta',\phi')\, \cos^2\alpha \tag{10}$$

This equation can be employed in conjunction with the minimum detectable signal level and the transmitting

ver level to determine the dynamic range over which directivity, $d'(\theta',\phi') = g'(\theta',\phi')/\eta$, of an antenna der test can be measured under a given situation. It is umed that the antenna under test is operated as a re- ving antenna; as previously, the primed quantities refer his antenna.

t is convenient to convert equation (10) to decibels simplify its application: [i]

$$L_r = L_o + G(\theta,\phi) + G'(\theta',\phi') - 20\log\left(\frac{4\pi R}{\lambda}\right), \quad (10a)$$

ere

L_r is the signal level at the output terminals of the receiving antenna in dbm,

L_o is the signal level at the input terminals of the transmitting antenna in dbm,

$G(\theta, \phi) = 10 \log g(\theta, \phi)$,

$G'(\theta', \phi') = 10 \log g'(\theta', \phi')$,

R is the transmitter-receiver separation, and $\cos\alpha$ is assumed equal to unity.

n making pattern measurements, especially of high antennas, it is often desirable to measure over at a 40 db dynamic range to adequately investigate the racter of the minor lobe structure of the antenna. der this assumption we can replace $G'(\theta', \phi')$ with $_{ax} - 40$ db. In addition, $G(\theta, \phi)$ will be replaced G_{max} since the transmitting antenna will be directed n its beam maximum in the direction of the test an- a. Under these conditions,

$$L_r = L_o + G_{max} + G'_{max} - 40 \text{ db} - 20\log\frac{4\pi R}{\lambda} \quad (10b)$$

is the receiving level when the test antenna is oriented hat a -40 db null is directed toward the transmitting nna.

or a low loss pencil beam antenna, if the antenna sep- ion can be set at $4d^2/\lambda$ and if G'_{max} is made equal $_{max}$,[j] a dynamic range of about 40 db can be achieved $L_o - L_{r\,min} = 60$ db. This condition is just barely izable, using typical klystron signal sources and direct ction. The actual situation often is less favorable than above case, making the achievement of sufficient dy- ic range using klystrons and direct detectors difficult mpossible. Relief from this situation must come from r more power or higher sensitivity. Signal Sources Receivers are discussed in Chapter III.

es of Antennas

is convenient to separate antennas into three types discussion of equipment and techniques for measuring characteristics.

he type includes high-gain microwave antennas such as used in radar. The wavelength is small compared the dimensions of the antenna, and the radiation pat- is due almost entirely to the field distribution across the aperture of the antenna. Currents on surrounding objects, such as the antenna mount, are small and contribute negligibly to the far-zone field. Antennas of this type will be called *microwave antennas.*

A second type includes lower gain antennas which usually operate in the UHF range and lower and which are mounted on aircraft or missiles. Large currents commonly flow over all or a considerable portion of the airframe and contribute strongly to the far-zone field. It is necessary to measure the antenna radiation characteristics while the antenna is mounted on the airframe, and it is further required to determine the antenna characteristics that exist when the antenna and airframe are far from the ground. Such measurements are often impossible to make directly. The usual procedure is to scale the wavelength and the antenna and airframe to dimensions of a reasonable size. Pattern measurements under simulated flight conditions are then made by mounting the model on a dielectric tower which is capable of rotating it about two orthogonal axes. Antennas whose patterns are measured in this manner will be called *model antennas.*

A third type of antenna encompasses low frequency antennas which are operated on either stationary or mobile mounts and which operate in close proximity to the ground or sea. Here again the size of the antenna precludes complete measurements of full-scale models. The wavelength and the antenna and its mount are scaled as in the case of the model antennas described above, and the measurements are made over a metal ground plane, which simulates the surface of the ground or sea. Antennas of this type will be called *ground-plane antennas.*

Pattern Range Coordinates

The radiation pattern of an antenna is described in terms of the field over a sphere of constant radius which is centered on the antenna under test. In making measurements on *microwave* and *model* antennas [k] as described above, the following technique is employed. Instead of holding the antenna fixed and moving a probe over the surface of the sphere to measure the pattern, the probe is held fixed, while the antenna under test is changed in direction. For convenience, the majority of antenna measurements are made on reception regardless of the application of the antenna since the radiation patterns are identical.

The logical coordinate system for use in making pattern measurements is the spherical coordinate system of Figure 1. The antenna is rigidly fixed in this coordinate system in its normal operating position; when the antenna is rotated to simulate movement of the probe, the coordinate system rotates with the antenna.

To permit making complete pattern measurements, it is necessary for the antenna positioner to have two axes of rotation which are orthogonal. Reference to Figures 5 and 6 will aid in picturing the correlation between the axes of the antenna positioner and the axes of the coordinate system of the antenna under test. Two positioner configurations are considered. These are commonly referred to as the *azimuth over elevation* positioner and the *elevation over azimuth* positioner. In setting up to make antenna measurements, one of the axes of the positioner in

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nomograph for evaluation of the last term of equa- (10a) will be provided at the conclusion to Part II, h will appear in the March issue.

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ee *Separation Between Antennas,* page 45.

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[k] *Ground plane* antennas are discussed in Chapter III.

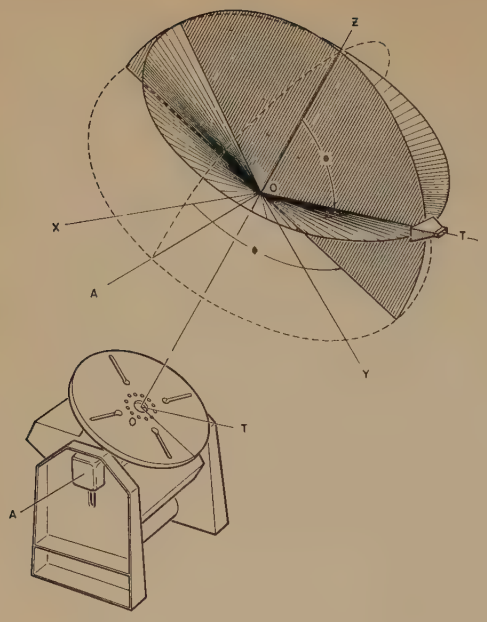


Figure 5 — Coordinates about Azimuth over Elevation antenna positioner

use is always oriented perpendicular to the line OT between the transmitting and receiving antennas. In Figures 5 and 6 this axis is referred to as axis A.

Figure 5 represents the coordinate system about an azimuth over elevation positioner. The size of the sphere is assumed to be very large compared with that of the antenna positioner and the antenna under test, which are located at O. The positioner is shown enlarged at the bottom of the figure in its orientation in the coordinate system and with the various axes drawn in. Note that axis A is fixed and perpendicular to line OT. The second axis of rotation is the Z-axis.

If the Z-axis of the antenna coordinate system is aligned with the Z-axis of the antenna positioner, the pattern cuts

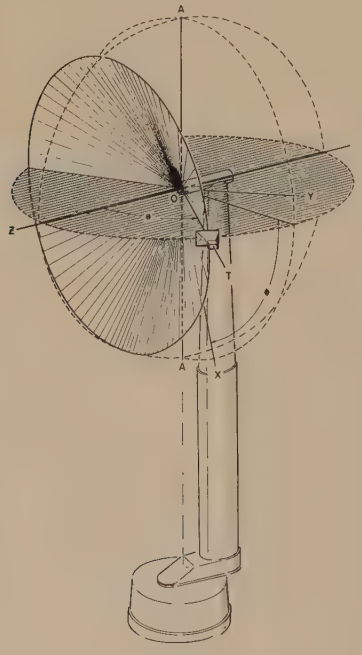


Figure 6 — Coordinates about Elevation over Azimuth antenna positioner

will be in the θ and ϕ directions of the antenna un test.[1]

The angle θ can be seen to be measured from the Z-a and the angle ϕ counterclockwise from the X-axis. Cuts the θ direction are made by rotation about the A-a These cuts are variously called *θ cuts, vertical cuts, lon tude cuts, elevation cuts,* and *orange peel cuts.* Cuts in ϕ direction are made by rotation about the Z-axis. Th cuts are called *ϕ cuts, horizontal cuts, latitude cuts, conical cuts.* The ϕ cut at $\theta = 90°$ and *any* θ cut *great circle* cuts. When great circle θ and ϕ cuts through the axis of the beam, they are usually referred as *principal plane* cuts.

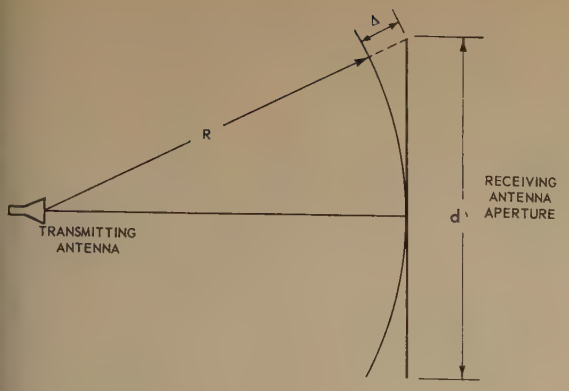
Figure 6 represents the coordinate system about an vation over azimuth positioner which in this case i model antenna positioner. If the line OT is horizontal, A-axis is vertical. Since the two axes are orthogonal, Z-axis of the positioner, which is mounted over the A-a is always horizontal as the A-axis rotates. To permit m ing true θ and ϕ cuts with the elevation over azim positioner, the Z-axis of the antenna under test is alig with the Z-axis of the positioner. Cuts in ϕ are a made by rotation about the Z-axis; cuts in θ are made rotation about the A-axis.

The elevation over azimuth configuration can also employed in microwave antenna positioners. With pro orientation of the antenna in the positioner, equiva cuts can be made through limited angles by use of ei type of positioner; the major difference between the is in the practical limit of the angles through which r tion is possible.

Siting Considerations [17]

Variation of the Phase of the Incident Field. Under erating conditions there is usually a large separation tween transmitting and receiving antennas, or, for a ra between the antenna and target. On the other hand, i desirable because of dynamic range considerations to m antenna measurements at as short a range as poss Since the measurements must simulate the operating s ation, it is necessary to know how great the separa between the transmitting antenna and receiving ante must be for the measured antenna gain and radiation terns to be a reasonable approximation of those w would be observed at extremely large separations. At tances from a transmitting antenna which are large c pared with the antenna dimensions, the phase fron the emergent wave is nearly spherical in shape. For treme separations, the radius of curvature is so large for all practical purposes the phase front can be consid plane between the extremities of a practical antenna. the antennas are brought closer together, a conditio reached that is shown in Figure 7; which shows a p antenna aperture of width d with a wave front of ra R tangent to the antenna at its center. Because of short radius of curvature, there is an appreciable se tion $\triangle$ between the wave front and the edges of antenna aperture. A criterion that is commonly empl

[1] If cuts are made over small angular regions, it ma be essential that this orientation be adhered to; the c encountered may be sufficiently small to be neglected



ure 7 — Spherical phase front tangent to a plane antenna aperture

determining the minimum permissible value of R is to d △ to a maximum of λ/16. A simple calculation will w that

$$R \geqq \frac{2d^2}{\lambda} \tag{2b}$$

required for this condition to be met.[m] The receiving nenna is then said to be in the *far zone* of the transmitg antenna.[18]

The major effect of a small deviation △ is to produce nor distortions of the sidelobe structure. Larger values △ will cause appreciable errors in the measured gain lobe structure.[19]

When making measurements on antennas which have e deviations in phase across the aperture on transmitg, such as optimum horns, it is necessary to make R siderably greater than $2d^2/\lambda$ to prevent excessive errors he measured gain and lobe structure.[20]

Variation of the Amplitude of the Incident Field. A sec- and important siting consideration is the variation of amplitude of the incident field over the aperture of test antenna. Excessive variations in the field will cause ificant errors in the measured maximum gain and lobe cture. This effect can be seen easiest from the viewnt of reciprocity. Variation of the amplitude of the l over the aperture on *receiving* is analogous to the *smitting* case of a modification of the aperture illumin- n by the primary feed. If the variation across the anna under test is limited to about 0.25 db, error in the surements will be negligible for most applications.[21] a transmitting antenna is employed which is calculated produce a marginally constant field over the antenna er test, it is essential that the transmitting antenna be urately directed so that the peak of its beam is centered he aperture of the antenna under test. Improper aim- which may not cause a sufficient loss of signal level it is noticed, results in an asymmetrical aperture mination and may give a false picture of the sidelobe cture. In the presence of phase errors caused by either antenna itself or by a marginally short siting distance, can cause apparently asymmetrical lobes in an antenna ch actually has a symmetrical sidelobe structure; conely, this condition can tend to mask asymmetrical lobe ctures which are actually present.

[m] A nomograph for determination of R for any value △ less than λ/6 is provided at the conclusion of Part which will appear in the March issue.

Separation Between Antennas. A convenient rule for determining the minimum distance between a pair of antennas in making antenna measurements is[22]

$$R = \frac{(d_1 + d_2)^2}{\lambda}, \tag{15}$$

where d_1 and d_2 are the aperture diameters.[n] This relationship represents a good approximation for testing most practical antennas.

In this same reference on page 902, an approximation is given for the ratio of the maximum power P_r which will be received to the power P_e which would be received in the absence of phase and field variation errors:

$$\frac{P_r}{P_e} \doteq 1 - 0.05\ (1/\lambda R)^2\ (d_1^4 + 6d_1^2\ d_2^2 + d_2^4). \tag{16}$$

This approximation is only good for values of $P_r/P_e > 0.9$.

Interference from Reflections. The requirement of providing adequate separation between antennas to prevent excessive phase error makes it difficult to satisfy a further requirement, that the site be free of large reflections from the ground. Addition of reflected fields at the test antenna can produce erroneous gain and pattern measurements. For instance, an interfering field which is 30 db below the peak of the main lobe can cause a variation of ± 0.25 db in the measured maximum gain and can seriously affect the measured sidelobe structure of the pattern. The usual methods of minimizing the effects of fields caused by reflection are to (1) mount the transmitting antenna and test antenna sites on towers, (2) employ a transmitting antenna which is as directive as permissible, (3) avoid smooth surfaces which are oriented so that they produce direct reflection into the test antenna, and (4) if necessary, erect screens or baffles to intercept the reflected wave near the reflection point.

An alternate procedure is to locate the transmitting and receiving antennas over a flat range and to take into account the specular reflection from the ground in making measurements. The height, h_2, of the antenna under test can be adjusted relative to the height, h_1, of the transmitting antenna to position its center at the maximum of the interference pattern between the direct and ground-reflected waves (See Equation B-3 of the appendix and Reference 6 of the Bibliography). Under these conditions the phase and amplitude of the field over an aperture of height $h_2/4$ are nearly enough constant that free space, far-zone conditions are simulated.

Acknowledgments

It was originally intended that this paper be written jointly by the author and Dr. John Taylor, formerly of Stanford Research Institute and Georgia Institute of Technology, now with Columbia Products, Incorporated.

[n] In testing fanned beam antennas, maximum signal can be achieved if the transmitting antenna has a beam that is fanned in the orthogonal plane to that of the antenna under test. Then, d_1 and d_2 are the maximum dimensions *in one plane;* the transmitting antenna gain is proportional to the *area* of the aperture.

Dr. Taylor's help in planning the paper and contributions to parts of the text are gratefully acknowledged.

The material help of Mr. Wayne K. Rivers and Dr. Maurice W. Long of Georgia Tech in reading and editing the manuscript is also acknowledged.

END PART I

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3. E. C. Jordan, *Electromagnetic Waves and Radiating Systems,* Prentice-Hall, Inc., Englewood Cliffs, N.J., pp. 333, 336, 417. The effective length defined above is the "generalized effective length" defined on page 336 of this reference.
4. Jordan, Op. Cit., p. 327.
5. Ibid.
6. F. E. Terman, *Radio Engineers Handbook,* McGraw-Hill Book Company, New York, 1943; p. 785.
7. Jordan, Op. Cit., p. 413, Kraus, Op. Cit., p. 27. Jordan calls the *directivity,* defined above, the *directive gain,* which is in accordance with IRE Standards on Antennas, 1948. However, there has been considerable variation among authors in antenna terminology; the terminology used here is not radical.
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22. Montgomery, Op. Cit., p. 900.

List of Symbols

The items in this glossary are presented in the order their appearance in the text.

Chapter I

ζ intrinsic impedance of space, $\zeta = \sqrt{\mu_o \epsilon_o}$.

$\vec{E}$ electric field vector with magnitude, E.

$\vec{H}$ magnetic field vector with magnitude, H.

η antenna efficiency.

I r-f current.

θ polar angle variable in a spherical coordinate system

ϕ azimuth angle variable in a spherical coordinate syste

$\vec{h}(\theta,\phi)$ effective length vector of an antenna presen to a direction (θ,ϕ) with magnitude $h(\theta,\phi)$

λ free space wavelength of a wave of frequency f $\frac{c}{\lambda}$.

c velocity of light.

β propagation constant of a wave with wavelength $\beta = \frac{2\pi}{\lambda}$.

r, R radial distances.

x, y, z cartesian coordinate variables; z is the "polar" a

d an antenna dimension.

Z an impedance; specifically,
Z_L a load impedance.
Z_a the impedance seen looking into the termi of an antenna.

V a potential.

x′, y′, z′ cartesian coordinate variables in a system ab a *receiving* antenna.

α the angle between the planes of polarization of rece ing and transmitting antennas when these pla contain the line passing through the two anten

$d(\theta,\phi)$ the directivity.

$\Phi(\theta,\phi)$ radiation *intensity;* implied is a power flow unit *solid angle.* Example of unit: watt per ste dian.

Φ_{av} average radiation intensity.

P power; specifically,
P_o total power at transmitting antenna termin
P_t total power radiated
P_r total power delivered to load of a receiv antenna.

d_{max} maximum value of the directivity, $d(\theta,\phi)$.

$\bar{d}'$ average value of the directivity.

$g(\theta,\phi)$ gain.

$P(\theta,\phi)$ power *density;* power flow through unit a normal to the direction of flow, (θ,ϕ). Exam of unit: watt per square meter.

$A(\theta,\phi)$ receiving cross section, an effective energy c ture area normal to the direction (θ,ϕ).

Chapter II

R resistance, used in formulae involving potential, c rent, and power.

n ratio of two values of power.

N ratio of two values of power expressed in db.

L power level expressed in dbm.

$G(\theta,\phi)$ gain expressed in db.

FERROELECTRICS AT MICROWAVE FREQUENCIES

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roduction

The most popular term for describing the electric prop-ies of an insulating material is probably "dielectric con-nt." However, it is no friend of the purist. It is some-es thought to denote only the epsilon in the formula for capacitance of a parallel plate capacitor, namely

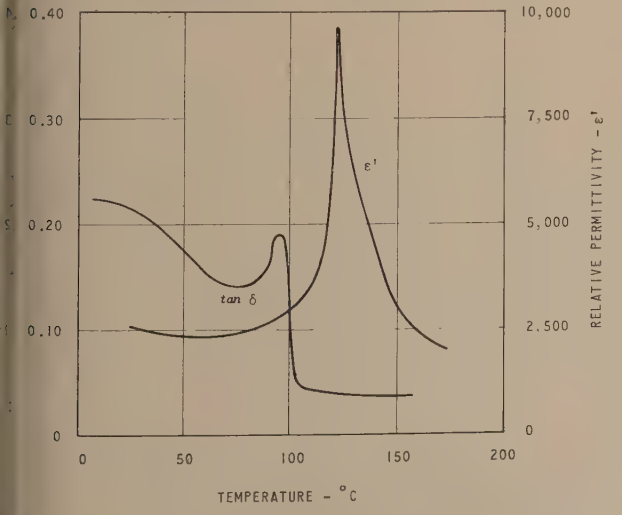
$$C = \alpha \cdot \frac{A}{d} \epsilon, \qquad (1)$$

where α = constant which depends on units
A = area of the plates
d = distance between plates
ϵ = dielectric constant or relative permittivity

s usage omits dielectric losses from consideration. The es are as important as the capacitance for many appli-ons. Two constants are sometimes combined in a "com-x dielectric constant" $\epsilon = \epsilon' - j\epsilon''$ in which the real part es the capacitance and the imaginary part describes the es when used in Equation (1).

For some materials, the complex dielectric constant is ependent of temperature and electric field. For ferro-ctrics, however, temperature dependence can resemble curves in Figures 1 through 4. The peaks in these ves are caused by abrupt changes in crystal structure, the temperatures at which they occur are called the ie temperatures or Curie points. In ferroelectrics, the ectric constant also depends upon electric field and depend upon frequency. Figures 5 and 6 illustrate e dependences. The somewhat unusual properties illus-ed by these curves are typical of ferroelectrics. In the ed ceramic shown in Figure 3, the Curie region is adened and shifted to a temperature which depends n composition.

The term "ferroelectric" is a misnomer. Ferro- is de-



re 1 — Dielectric Behavior of Ceramic Barium Titanate (After Von Hippel [5])

rived from ferrum, Latin for iron, and when used in the combined form means "containing iron." However, there are no ferrous materials in ferroelectrics. The term "ferro-electric" was coined by analogy. Both ferroelectric and ferromagnetic materials exhibit a hysteresis loop, as illus-trated in Figure 7. The horizontal axes represent the ex-ternal polarizing force while the vertical axes show the effect produced by it. Magnetic fields are not involved in ferroelectric phenomena, and "non-linear dielectrics" would be a better term for these materials.

Characteristics of Ferroelectrics

Ferroelectrics come in crystalline and ceramic forms. Some miniature capacitors owe their small size to the high dielectric constant of a ferroelectric ceramic. Ferroelectric ceramics are also used in temperature compensating ca-pacitors to prevent thermal drift in tuned circuits. Single ferroelectric crystals are being developed for computer memories. A single domain crystal has a polarization which is either up or down and can be reversed by an applied electric field. If its physical properties are adequate in other respects, it can be used as a binary memory element.

Pockels first reported the anomalous properties of Ro-chelle salt in 1894. Since then, about fifty ferroelectrics have been discovered. For study purposes,[8, 9, 11] these are usually grouped according to crystal structure. In most cases the crystal structure furnishes a model which explains the existence but not the magnitude of ferroelectric effects. The models are based upon anisotropic motion of ions or electrons in the crystal. For ferroelectrics of the barium titanate group, a thermodynamic theory [7] connects the vari-ous experimental data semiquantitatively. Above 120° C the barium titanate crystal may be visualized as a cube with a barium ion at each corner, an oxygen ion at the center of each face, and a titanium ion at the center of

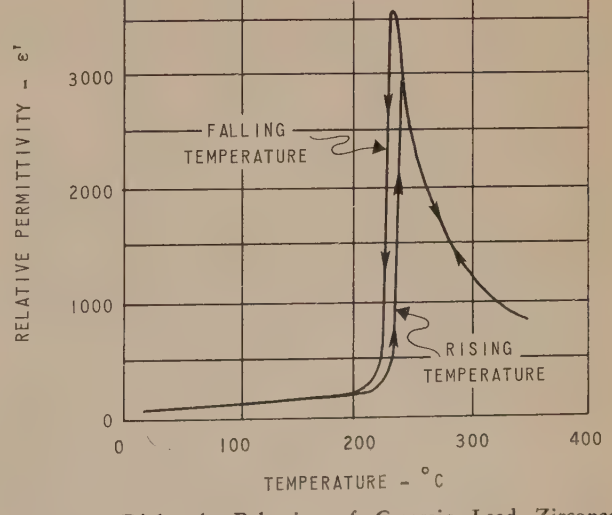


Figure 2 — Dielectric Behavior of Ceramic Lead Zirconate (After Roberts [8])

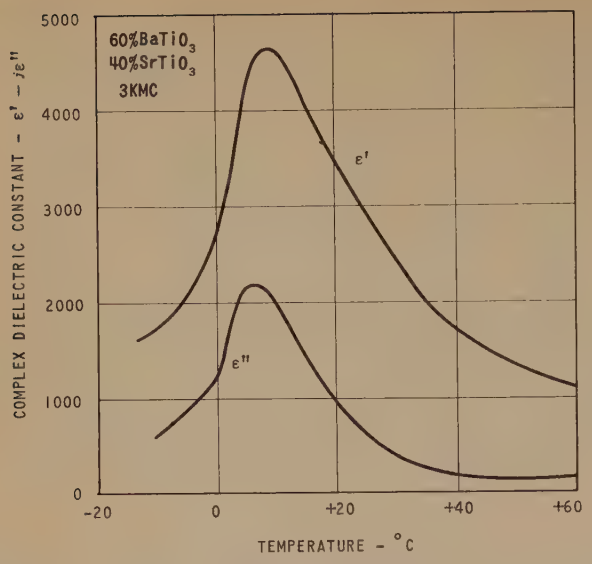


Figure 3 — Dielectric Behavior of Mixed Barium Strontium Titanate (After Sharpe and Brockus [24])

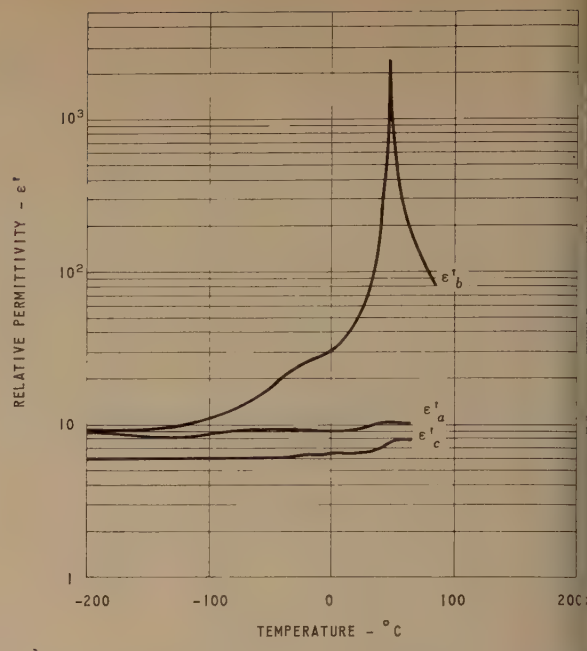


Figure 4 — Dielectric Behavior of Triglycine Sulphate al its Three Crystalline Axes (After Hoshino et. al.[25])

the cube. Below 120° C, the lattice shrinks enough to squeeze the titanium ion slightly out of its central position. In its new position the titanium ion can move much less freely in one direction than in the others, making the dielectric constant lower in the direction of the restricted motion. The variation of dielectric constant with direction in the crystal makes it optically birefringent and produces other effects. One of these is that an applied dc field moves the titanium ion into regions within which it is less free to move. The dielectric constant is therefore decreased by an externally applied field.

A similar mechanism accounts for ferroelectricity in potassium dihydrogen phosphate. In compounds with this structure a hydrogen ion can move between two stable oxygen bond configurations. Ordering of the hydrogen bonds has been verified by neutron diffraction experiments.[26] Many other ferroelectrics seem to involve mechanisms of this type.

Colemanite ($CaB_3O_4(OH)_3H_2O$) probably has a chain of molecules in which electrons can move more easily along the chains than across them. This produces the dielec anisotropy.

None of these structural models can be made quann tive until the internal fields are known in which the i or electrons move.

Domain switching is an important low frequency ef in ferroelectrics. In developmental work toward comp applications, attempts were made to use the square hys esis loop of barium titanate single domain crystals memory purposes. For reasonable field strengths, a lo limit was discovered for the time required to switc domain.[24] The corresponding frequency limit is in

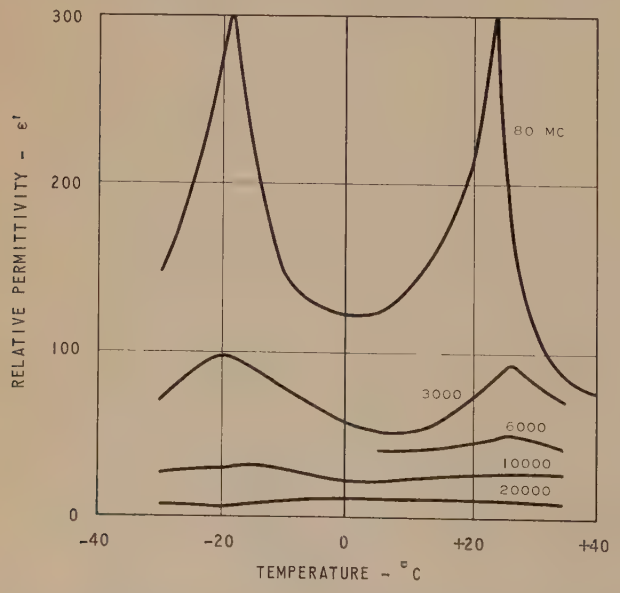


Figure 5 — Dielectric Behavior of Rochelle Salt (After Akao and Sasaki [13])

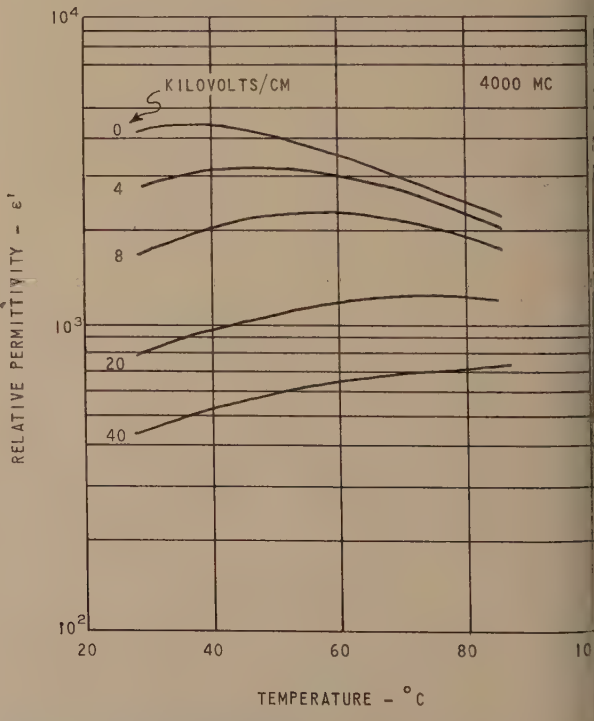


Figure 6 — Dielectric Behavior of Aerovox HiQ91 Cer (Authors Measurement)

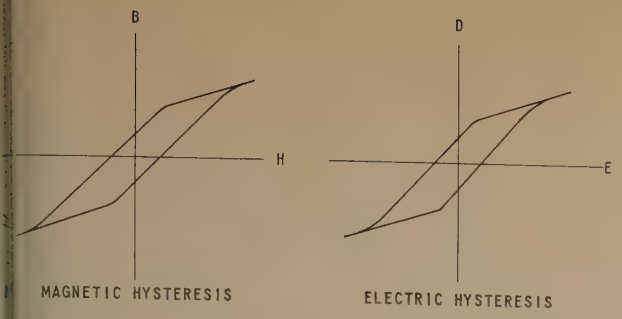


Figure 7 — Ferromagnetic-Ferroelectric Analogy

gacycle range for the materials investigated. More ent work [25] has shown that microwave fields greater n 150 kv per cm would be required to cause micro- ve losses through the mechanism of domain wall tion.

crowave Properties

ittle information has been published concerning the crowave properties of ferroelectric materials.* It is eved that hysteresis is absent, or very nearly so, for quencies in the microwave range. The ferroelectrics most ly to find practical microwave application in the im- diate future are those having highly non-linear dielectric racteristics, and, preferably, negligible hysteresis at all quencies. It is expected that these materials can be used microwave frequencies in much the same way that volt- sensitive semiconductor diodes (such as the Varicaps le by Pacific Semiconductors, Inc.) are used at low quencies. To be suitable for such use the ferroelectric t have a dielectric constant which takes on a wide range values depending on an applied biasing field.

Microwave measurements have been made at Sylvania's tronic Defense Laboratories on a number of ferroelec- ceramics. These are commercially available materials d principally in the manufacture of low frequency mini- e capacitors. Figure 8 shows the measured small-signal lectric constant as a function of externally applied dc tric field for one of the ferroelectrics. The measure- ts were made at room temperature and 1000 mc.** dielectric constant drops from about 4200 with no to about 560 with 40 kv per cm applied dc electric . Losses shown in Figure 9 are not so high as to pre- use in many applications.

rowave Applications

The unusual characteristics of the material of Figure 8 be used to make a voltage variable microwave capaci- The region between capacitor plates is filled with oelectric material. When a dc control voltage is ap- d to the capacitor plates it alters the bias field and efore the dielectric constant of the ferroelectric. The citance is thus changed. The data illustrated in Figures d 9 were obtained in just this way. A coaxial trans-

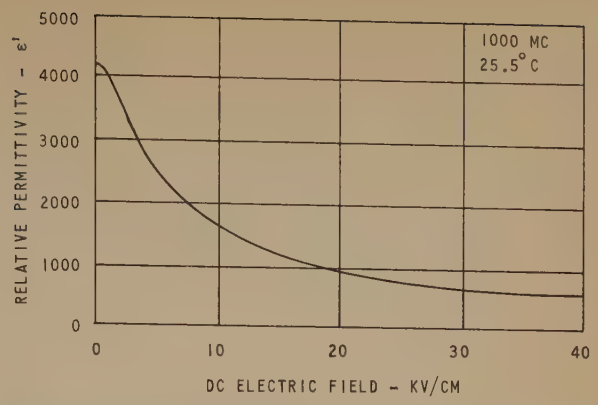


Figure 8 — Field Dependence of Glenco K-9000 Ceramic (Authors Measurement)

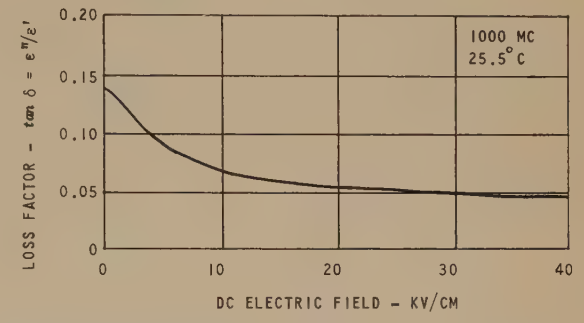


Figure 9 — Dielectric Losses of Glenco K-9000 Ceramic (Authors Measurement)

mission line was terminated by a tiny ferroelectric capacitor similar to those in Figure 10. Slotted line measurements were made of the impedance of the capacitor at 1000 mc under a range of dc bias conditions. Dielectric constant was calculated from the impedance data and the known dimensions of the test sample.

Several properties of this ferroelectric combine to dictate the form in which it can be used in microwave applications. First of all, the average dielectric constant is very high. This necessitates that electrodes for application of control voltage be in intimate contact with the ferroelectric material. Secondly, extremely high dc electric fields are required to effect large changes in the dielectric constant. For this reason the spacing between electrodes must be small. For instance, to obtain the 40 kv per cm electric field of Figure 8 with a 1000-volt supply, the spacing between electrodes (capacitor plates) can be only 0.25 mm, or 0.010 inch. The small spacing between capacitor plates and the high average dielectric constant combine to impose

Figure 10 — Ferroelectric Capacitors and Point of Ordinary Pin (Magnification about 50)

n the bibliography of reference 6, only 25 of the 1200 refer- s mention microwave properties.

The dielectric constant (real part) of this particular material determined to be essentially independent of frequency in the e 500 to 4000 mc.

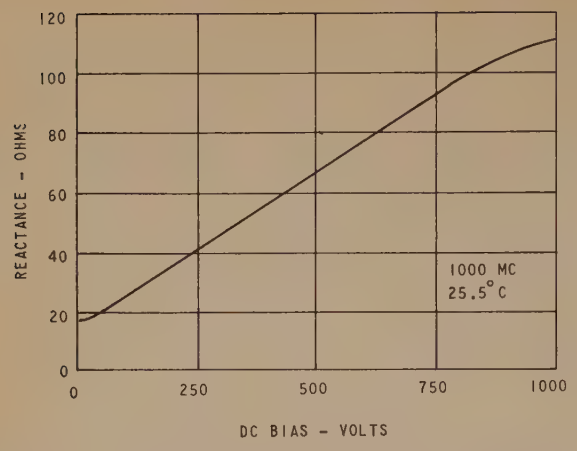


Figure 11 — The Capacitive Reactance of a 0.010 inch Ferroelectric Cube.

the further restriction that the cross-sectional area of the capacitor be very small. If the area of the capacitor is too large the capacitance will be excessive for use at microwave frequencies.

The ferroelectric elements photographed in Figure 10 are typical of the size required in most circuits at 1000 or 2000 mc. The dimensions of each are roughly that of a cube 0.010 inch on a side. The capacitive reactance at 1000 mc is plotted in Figure 11. The magnitude of the reactance is about right, depending on the application, for use in 50-ohm coaxial or strip line circuits. At higher microwave frequencies still smaller capacitors will be desirable.

The large variation of capacitive reactance with voltage (Figure 11) suggests that ferroelectrics can be used for wide range control of the resonant frequency of a microwave circuit. One way to do this is illustrated in Figure 12. The ferroelectric element provides a voltage-variable end capacitance for the coaxial cavity. At the design center frequency the portion of the cavity above the choke is approximately an eighth-wavelength. The choke section permits application of control voltage to the ferroelectric element while approximating a short circuit at plane "A" for the frequency range of interest. Coupling loops serve to bring signal energy into, and out of, the cavity.

As viewed from the terminals of the ferroelectric capacitor the main portion of the cavity is a coaxial transmission line short-circuited at plane "A." The length of this portion is less than a quarter-wave and therefore presents an inductive reactance to the terminals of the ferroelectric capacitor. The resonant frequency of the cavity is the frequency at which the capacitive reactance of the ferroelectric element is equal to the inductive reactance of the remainder of the cavity. The capacitance of the ferroelectric element is controllable by an applied voltage, and therefore, so is the resonant frequency of the cavity.

A voltage tunable cavity similar to that shown in Figure 12 was built with a design center frequency of 600 mc. When a ferroelectric element was used which had slightly more capacitance than the one of Figure 11, the resonant frequency of the cavity could be varied over an octave by using voltage control alone. Figure 13 is a multiple exposure photograph of a swept oscilloscope trace. The vertical scope axis is proportional to power transmitted through the cavity. The "X" axis is synchronized with a swept frequency source. Each trace describes the transmission characteristics of the cavity at a particular dc bias voltage.

The cavity Q is very low by microwave standards. This is due to the dielectric losses of the ferroelectric. For wide control of resonant frequency it is necessary that the microwave electric fields be concentrated in the ferroelectric. When this is done the unloaded Q of the cavity is approximately equal to the Q $(1/\tan\delta)$ of the ferroelectric. The unloaded Q of the cavity was 9 at 430 mc, increasing to 45 at 880 mc. The cavity could be designed to store appreciable microwave electric energy in the circuit outside the ferroelectric. Although this would increase the cavity Q, it would decrease the frequency range over which the cavity can be voltage-tuned. For voltage tunable filter applications, skirt selectivity could be increased considerably by using several ferroelectric elements in a more complicated circuit.

In addition to voltage tunable filters, other microwave devices to which ferroelectrics can be applied are voltage tunable oscillators, phase shifters, impedance matching networks and attenuators. In most of these applications the ferroelectric element may be in the form of a small cube, silvered on two opposing sides. An interesting shape thought to be practical, is a long narrow strip, silvered on top and bottom. The ferroelectric strip, with electrodes, is a parallel plate transmission line with voltage variable dielectric.

Problems

In voltage tuning applications using those ferroelectrics whose microwave characteristics are presently known

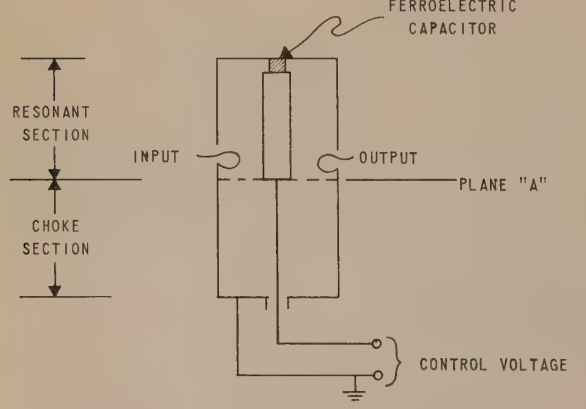


Figure 12 — A Voltage Tunable Cavity

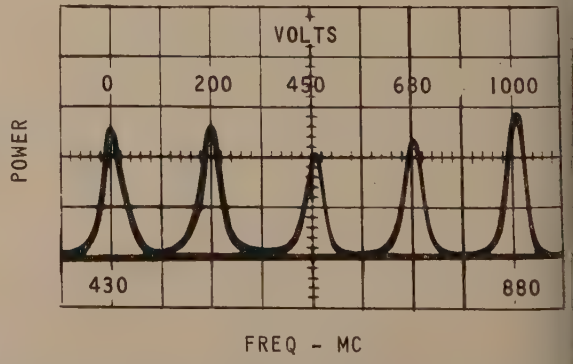


Figure 13 — Resonances of Cavity Tuned by Ferroelectric Capacitor, at Several Control Voltages.

two of the dimensions of the ferroelectric element be very small, say 0.010 inch. This creates some al problems in the preparation and handling of these rials. Both ceramics and the crystalline materials are and brittle and tend to shatter easily. A thin diamond el was used to cut the ceramic elements of Figure 10 a thin silvered disc. Elements having half this cross- n have been successfully prepared in this way. Crys- e ferroelectrics can be shaped by sand blasting.

essure contact was used for electrical connection in experiments using the slotted line and the coaxial y. The applied dc bias fields approached that of break- n in clean dry air. In both sets of experiments it was ssary to make provisions for dry air in the vicinity of ferroelectric element to prevent voltage breakdown e air path. In practical voltage tunable devices the electric elements may be soldered into the circuit and potted against moisture. Some of the new polystyrene- l potting compounds appear to be suitable for this ose. Several ferroelectric capacitors, potted as de- ed, have withstood dc electric fields as high as 160 kv m.

cause most ferroelectrics are extremely good insula- the power supply requirements are not severe. While control voltages are required to achieve large varia- in the dielectric constant, the dc resistivities are so that control current and power requirements are gible. The resistivity of ferroelectrics is typically of order of 10^{12} ohm-cm.

more important factor for many applications is the erature dependence of the dielectric constant. Usually, erroelectrics which are the most voltage sensitive are the most temperature sensitive. Where capacitance be controlled over a wide range by voltage and where tions with ambient temperature cannot be tolerated, the only solution with presently known materials is erature control of the ferroelectric element.

e microwave circuit surrounding the ferroelectric l be held at a constant temperature in a number of . For example, temperature control methods similar ose used for quartz crystals could be employed.

nother possibility is to engineer the ferroelectric com- ion for a particular application. By introducing small ities of properly chosen additives into the ferroelec- its temperature sensitivity could be reduced without ortionate reduction in its voltage sensitivity.†

clusion

rroelectrics now available can be useful in some mi- ave applications. New materials are being discovered new combinations of old materials are being made. er application of ferroelectrics will be made as mate- with improved Q and voltage sensitivity are found.

rivate communication, H. H. Wieder, U. S. Naval Ordnance ratory, Corona, California.

is work was supported by the U.S. Army Signal Corps under act DA 36 039 SC-78281

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NOISE TEMPERATURE IN PASSIVE CIRCUITS

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I Introduction

The advent of extremely quiet microwave amplifiers compels a close examination of noise sources preceding the first low noise amplifier in microwave receiving systems. One important category of noise sources is the one encompassing the various passive regions propagating the signal. The present discussion is primarily a tutorial one, including several pertinent points of view, concerning noise temperature.

Most of the analysis assumes a uniform temperature for each transmission region considered. Reference is made to the non-uniform temperature case encountered primarily in dealing with the earth's atmosphere. The concept of component and systems temperature is the principal one utilized. The relationships of noise factor and the corresponding noise figures to these temperatures are also indicated.

II Noise Power From Passive Circuits

The designer of microwave circuits needs to be able to calculate the noise output of the type of circuit shown in Figure 1. A basic question is, "How much is the noise power output changed by inserting a four-terminal network between a source and an output port?"

Pawsey and Bracewell[1] treat the problem by starting with the basic physics of absorbing propagating regions.

They derive a brightness temperature.

$$T_b = \int_o^\infty \exp\,[-\delta]\; T_p d\delta \qquad (1)$$

where T_b = the brightness temperature of an absorbing medium extending to infinity from the point of observation.

T_p = the thermal equilibrium temperature of the absorbing medium. This may be constant or be a function of the element position P.

α = the attenuation factor in nepers per unit length. It may vary with path position.

δ = the optical or attenuation depth = $\int_o^P \alpha\, ds$

ds = a path length element = dp

$d\delta = \alpha\, ds$, an attenuation thickness for an element of absorbing material in nepers.

It is to be noted that the factor $[\exp(-\delta)]$ is attenuation experienced by energy propagating from contributing element to the point of observation. [situations where T_p and α are functions of the p element position

$$T_b = \int_o^\infty \exp\,\left[-\int_o^P \alpha(P)dp\right]\; T_p(P)\alpha(P)ds$$

If the first portion of the path from the observat point to a given path position P_1 is at a constant t perature, T_p,

$$T_b = T_p \int_o^{\triangle} \exp\,[-\delta]\; d\delta + \int_{P_1}^\infty \exp\,\left[-\int_o^P \alpha ds\right]\; T_p$$

$$T_b = -T_p \Big[\exp(-\delta)\Big]_o^{\triangle} + T_b(P_1)\exp\,[-\triangle]$$

$$= T_p\,[1 - \exp(-\triangle)] + T_b(P_1)\exp\,[-\triangle$$

Where $T_b(P_1)$ = the apparent brightness temperat due to all contributors beyond the path position

$\triangle = \int_o^{P_1} \alpha(P)ds$, an attenuation depth from the ori to P.

But, $[\exp \triangle] = L$, defines the loss factor.

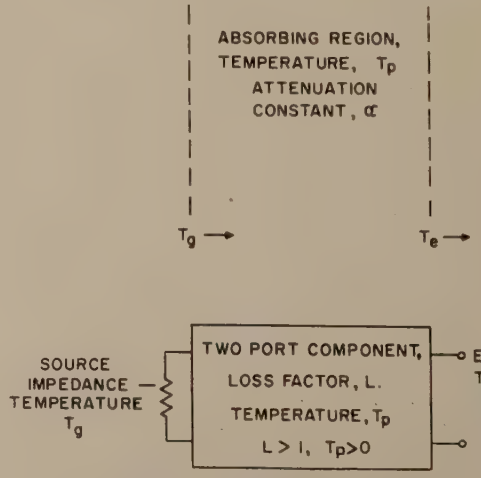

Figure 1 — Basic noise temperature

$_b = T_p\ [1 - L^{-1}] + T_g L^{-1}$

ere $L > 1$ and all temperatures are greater than
). However, $T_b \lessgtr T_b(P_1)$ depending upon L
T_p.

trum [2] has called this the effective temperature,

$$T_e = T_p\ [1 - L^{-1}] + T_g L^{-1}, \qquad (3)$$

g $T_g = T_b(P_1)$ to represent the apparent source
perature as shown in Figure 1.

he two equations (2) and (3) applied piecewise per-
evaluation of the effective temperatures of all the
ive transmission components needed in systems cal-
tions. Before (2) can be utilized the temperature
ction T(P) and the attenuation function $\alpha(P)$ must
known. Some results for a theoretical treatment of
effective temperatures for the non uniform at-
phere have been given recently by Pierce and
npfner.[3]

bsorbing regions at uniform temperature are easily
ted as shown by equation (3). Three points of view,
d on variations of equation (3) have been utilized
various individuals. These points of view can be
marized by the equations

$$T_e = T_p\ [1 - L^{-1}] + T_g L^{-1} \qquad (4)$$

$$\triangle T = T_e - T_g = (T_p - T_g)(1 - L^{-1}) \qquad (5)$$

$$T_x = T_p\ [L - 1] = T_e L - T_g = (\triangle T)\ L + T_g(L - 1) \qquad (6)$$

se equations define the three temperatures T_e, $\triangle T$,
T_x. Equation (4) is easily interpreted. The first
$T_p\ [1 - L^{-1}]$ accounts for reradiation energy
to the propagation region, having loss L and tem-
ture T_p. The second term accounts for the source
gy, attenuated by the factor L^{-1} in traversing the
ified two port network. The effective temperature,
, is proportional to the entire noise power output
to a source and a network which is also a source of
e power.

y assuming that $T_g = 0°K$ and $T_p = 290°K$ a few
inent values of T_e, the effective temperature, have
calculated and are tabulated below.

Transmission Circuit Loss

Factor (L)	Decibels	T_e (°K)
1.25	1.0	58
1.12	0.5	31
1.06	0.25	16
1.02	0.1	6

igure 2 presents a group of curves showing the rela-
ship relative to a reference temperature, the ratio
T_g (or t_e/t_g in normalized form) and several values
T_p as a function of loss factor. All the temperature
es have been normalized to 300°K. Three curves
plotted for $t_g = 1/15$ ($T_g = 20°K$), and one curve
$t_g = 1/2$ ($T_g = 150°K$).

osses up to 1 db can be tolerated in some systems
g some of the new low noise amplifiers. Notice, in
re 2, that for $t_g = 1/15$ and $t_p = 1.0$ a 0.1 db loss
lts in a temperature ratio, t_e/t_g, of 1.3. For low
ce temperatures, individual component losses of
db will justify extensive future development effort
btain reduction of such a loss.

quation (4) shows that the noise output of a passive

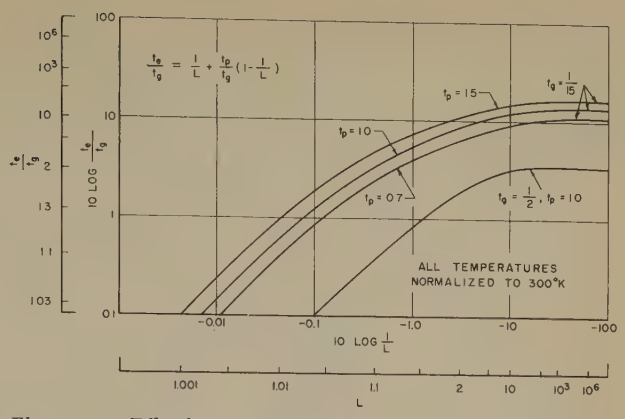

Figure 2 — Effective temperature is a function of loss factor

two port network depends upon the temperature of the source coupled to the input port. In systems calculations it is often convenient to talk about the change in noise level caused by the insertion of a two port network or propagation region. This is given by equation (5). It might be called an incremental temperature $\triangle T$. It is not a quantity which is a characteristic of the network alone, so it is not comparable to an absorption function. However, its source dependence appears only in the factor $(T_p - T_g)$. This permits use of a single graph to represent it for all two port networks. This is given in figure 3. In normalized form, it is essentially the graph of the absorption, $(1 - L^{-1})$. To obtain $\triangle T$, this must be multiplied by the temperature difference, $T_p - T_g$, which is jointly dependent upon the source and component temperature.

It is to be noted that $\triangle T$ can be either negative or positive, $\triangle T \lessgtr 0$. It becomes negative, $(T_e - T_g < 0)$ when $T_p < T_g$. This merely says that an absorbing passive component, at a temperature lower than the source, will result in a noise output less than that of the source. It is also true that an absorbing passive component, at a temperature higher than the source must result in a noise output greater than that of the source.

In both these cases, equations (4) and (5), the physical fact that the noise output depends on the input temperature remains, and mere rearrangement of the algebra for convenience in computation should not be expected to remove this dependence.

The temperature defined in equation (6) has been called the noise temperature by Ewen.[4] Here, it will be called effective input noise temperature in conformity with a definition suggested by the IRE Sub-committee

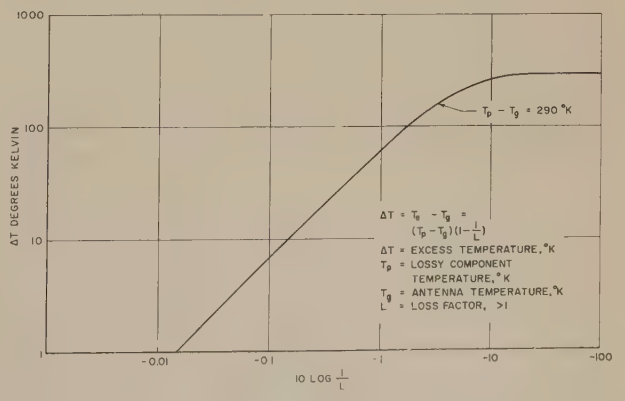
ΔT DEGREES KELVIN
$T_p - T_g = 290°K$
ΔT = EXCESS TEMPERATURE, °K
T_p = LOSSY COMPONENT TEMPERATURE, °K
T_g = ANTENNA TEMPERATURE, °K
L = LOSS FACTOR, >1
10 LOG $\frac{1}{L}$

Figure 3 — Incremental temperature as a function at loss factor

7.9 on noise.[5] Its properties can be discussed by a signal to nosie ratio calculation. For the network of figure 1, the degradation factor referred to by Hansen,[6] is,

$$F(T_g) = \frac{\frac{S_i}{N_i}}{\frac{S_o}{N_o}} = \frac{\frac{S_i}{kT_gB}}{\frac{S_i}{LkT_eB}} = \frac{T_eL}{T_g}$$

$$= \left[\frac{T_g}{L} + T_p\left(1 - \frac{1}{L}\right)\right]\frac{L}{T_g}$$

$$F(T_g) = [T_g + T_p(L-1)]\frac{1}{T_g} \qquad (7)$$

If the entire loss in signal to noise ratio is charged to the temperature of the component, of loss L and temperature T_p, then the entire effect of adding the two port network is to raise the apparent input temperature of the component by $T_p(L-1)$. This quantity has a limit of ∞ for large L. Using it as a part of the effective input noise temperature is equivalent to saying a component having large loss L degrades the sensitivity because its excess temperature has gone to infinity rather than saying its signal level has gone to zero.

This procedure does define an effective input noise temperature seemingly dependent on the properties of the component alone, i.e. T_p and L. However, in exchange it gives the impression that the noise level due to this temperature of a passive component can be larger than its ambient temperature. In cases where actual signal and noise levels need to be derived at each connection between components, this type of calculation gives signal and noise levels exceeding the actual levels by a factor of L.

Nevertheless, the signal to noise levels will be correct if the computation is for cascaded passive components only. When an attenuating two port network is inserted in a system, the only data required to evaluate its contribution to the temperature are properties of the two port itself, its temperature and its loss factor. This feature alone is already leading to wide use of T_x, here called effective input noise temperature.

These facts can be shown for cascaded circuits as shown in figure 4.

The effective temperatures at the outputs are defined as T_{e1}, T_{e2}, . . .

$$T_{e1} = \frac{T_g}{L_1} + \left(1 - \frac{1}{L_1}\right)T_1 \qquad (8)$$

$$T_{e2} = \frac{T_{e1}}{L_2} + \left(1 - \frac{1}{L_2}\right)T_2 \qquad (9)$$

Putting (8) into (9)

$$T_{e2} = \frac{1}{L_2}\frac{T_{g1}}{L_1} + \left(1 - \frac{1}{L_1}\right)T_1 + \left(1 - \frac{1}{L_2}\right)T_2$$

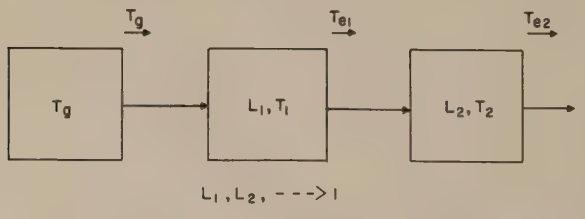

Figure 4 — Cascaded passive circuits

$$= \frac{T_g}{L_1L_2} + \frac{(L_1-1)T_1}{L_1L_2} + \frac{(L_2-1)L_1T_2}{L_1L_2} \qquad (1$$

$$= \frac{T_g + (L_1-1)T_1 + (L_2-1)L_1T_2}{L_1L_2} \qquad (1$$

In equation (10) the three terms can be identified as

$\frac{T_g}{L_1L_2}$ = source energy arriving at the output component 2

$\frac{(L_1-1)T_1}{L_1L_2}$ = reradiation energy of component 1 riving at the output of component 2

$\frac{L_2-1}{L_2}T_2$ = reradiation energy of component 2 arr ing at the output of component 2.

The numerator of equation (11) has the effect input noise temperature terms $T_{x1} = (L_1-1)T_1$ a $T_{x2} = (L_2-1)\,L_1T_2$. To secure the actual noise lev these must be divided by $L_1\,L_2$.

Equations 10 and 11 can be extended to any numb of components by induction.

The three temperatures, T_e, $\triangle T$, and T_x can be lated to the noise factor, the degradation factor, a the sensitivity factor given by Hansen.[6] One of th relationships is given in equation (7).

Conclusions

At least three useful noise temperature expressio associated with passive components have been discuss and their interrelations derived. It is apparent that a quate systems computations are easily made when losses and temperatures are known for passive com nents at uniform temperatures.

The noise temperature concepts can also be used propagating regions at non-uniform temperature. Ho ever, suitable effective temperatures have been compu only in a limited number of cases. These cases are c fined, so far, to an idealized atmosphere.

The literature now contains suitable definitions of noise factor and noise temperature type. Their in relations have been shown. Some sort of standardizat will become pertinent in the near future.

Acknowledgment

This paper has been reviewed by W. W. Mumf and G. M. Branch who have shown a sustained inte in these problems. Their suggestions have been v helpful and many of them have been incorporated this final form.

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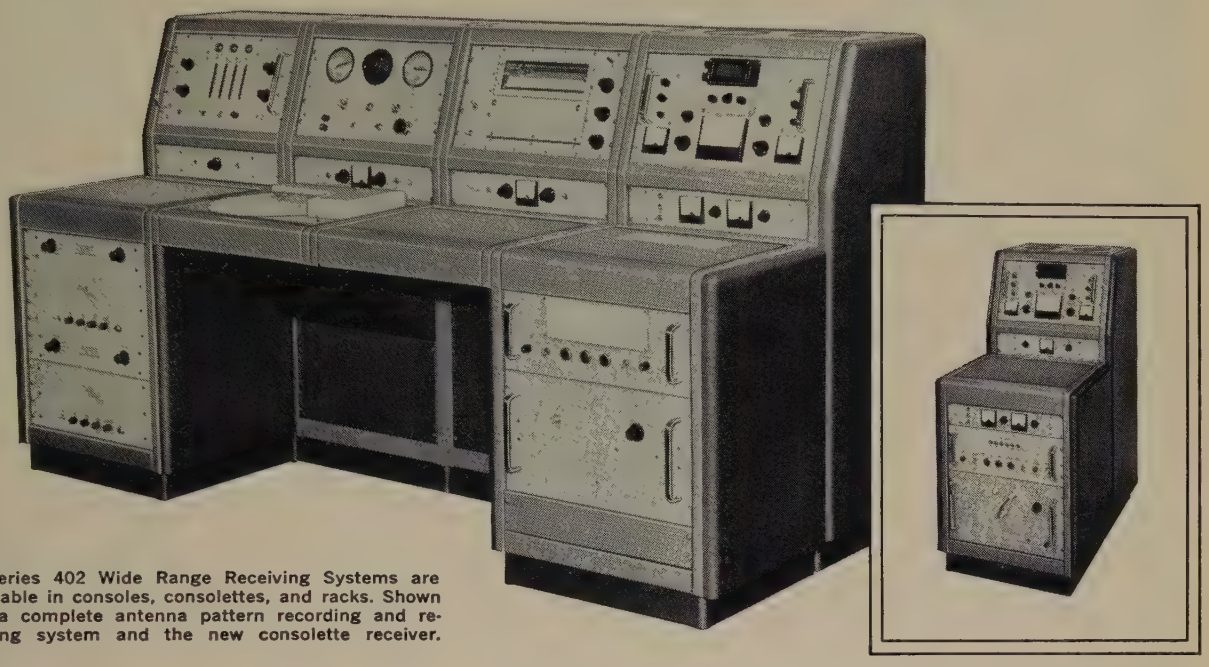
MAJORS and MINORS

...A Message to the Antenna Designer



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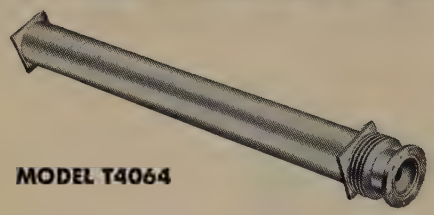

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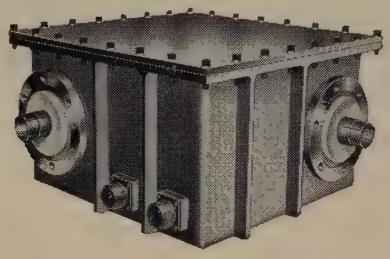
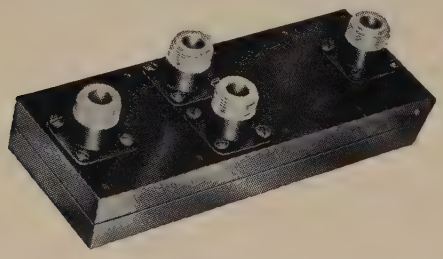


4441 COAXIAL SWITCH

MODEL T4441
Equivalent to JAN SA-602/U

The Bogart Model T4441 Coaxial Switch resulted from a program to develop an extremely small and compact, yet reliable device for aircraft applications. Many coaxial switches currently in use incorporate metallic "fingers" or sliding shorts to achieve the switching action. The continual maintenance that was required by the Armed Forces led to a request for a coaxial switch that would be novel in operation; avoiding the time honored use of sliding metallic "fingers." This has been achieved in the Bogart T4441.

A unique arrangement of non-contacting vanes eliminates the wear and contact problems inherent in most coaxial switches, yet maintains an excellent electrical characteristic. An unusually high degree of isolation for a non-contacting type switch is offered.



5805 COAXIAL BALANCED BAR HYBRID*

MODEL NL5805

The growth of the guided missiles field has provoked increased engineering activity directed towards the miniaturization of microwave components. Special techniques and materials have been developed to conform with severe space limitations and extreme temperatures. The Bogart series of bar hybrids has found wide use in military and commercial applications as **balanced mixers** (coaxial crystal mounts are available as accessory equipment), **power splitters, phase comparators, variable power dividers, fixed and variable attennators, phase shifters** for monopulse work, **duplexers** to permit design of complete coaxial R-F heads composed entirely of hybrids, and **beacon switching devices.**

A brochure entitled "Applications Employing Coaxial Bar Hybrids", in which the Bogart hybrids are presently used to perform the previously described functions, is available upon request. Special applications of Bogart Bar Hybrids can be designed to meet your specific requirements.

For characteristics of coaxial crystal mounts, refer to Bogart Series 1032.

*PATENT PENDING

BOGART

BOGART MANUFACTURING CORP.
serving the electronics industry since 1942 design • development • production
315 Seigel Street Brooklyn 6, New York

Circle Reader Service Card 34

Industry News

(*Continued from page 33*)

This move was dictated by the n for additional laboratory, office and s space.

With this move, Merrimac will r have two operating sections, Mr. Jos D. Cappucci concentrating on commer sales and Mr. David Friedman on search and development programs.

Mr. Cappucci will expand the Me mac line of zero insertion loss varia attenuators, to cover the full microw spectrum, and expand production broad band filters, directional coupl and related microwave components.

Mr. Friedman will be doing resea and development, primarily in the f of advanced microwave components, tremely broad band hybrids, varia power dividers, coaxial circulators, other unique microwave devices.

Mr. Friedman was formerly with Westinghouse Corporation, Electron division, Baltimore, Maryland.

— *m w j* —

TORGOW JOINS PRD

Eugene N. Torgow has joined the gineering Division of the Polytech Research & Development Co., Inc., a Department Head of Special Products.

Mr. Torgow was born on Novem 26, 1925 in New York, New York. received the B.E.E. Degree from Cooper Union School of Engineer New York, N.Y., in 1946, and the M.E degree from the Polytechnic Institute Brooklyn, N.Y., in 1949.

During 1946-47, he served with U.S. Army Air Force, doing radar re and miantenance in the Pacific Thea In 1948, he joined the staff of the Mi wave Research Institute of the Polyte nic Institute of Brooklyn, where worked on research and development microwave attenuators, and power m uring devices. From 1951 to 1953, established and supervised a microw laboratory at the Allen B. DuMont L oratories, East Paterson, New Jersey.

(*Continued on page 58*)

OW TO MEASURE ATTENUATION

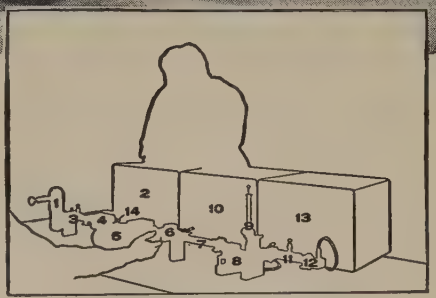
microwave bench set-up is for the measurement of attenuation he RF SUBSTITUTION method. Other techniques could have been vn, but this represents one of the simplest, easiest to use methods vn.

e one main point we would like to stress is: regardless of the kind of surements made, the quality of the test equipment used is of the ost importance. That's why PRD has concentrated on producing the **est** range of the **most precise** microwave test equipment available vhere in the world.

the RF SUBSTITUTION method, the PRD 195-B Precision Gauge nuator is used as a standard and calibrated for the frequency at h the attenuation is to be measured. The PRD 195-B is set at e value of attenuation greater than the unknown. Its reading and output power level of the line shown on the PRD 650-B Power Bridge both recorded. The unknown is then inserted into the line thereby nging the output level, and the PRD 195-B is readjusted to return the er level to its original value. The attenuation of the unknown is simply difference between the two readings of the PRD 195-B.

ound Simple? Sure it is, but even more important it's accurate. The 195-B has a guaranteed calibration accuracy of ± 0.2 db.

e precision and ease of operation of all of the products shown in this nple are typical of each of over 300 PRD microwave test instruments ently produced. For detailed specifications of the products shown e measurement bench, write:



TEST INSTRUMENTS USED IN THIS X-BAND ATTENUATION BENCH

1—703 Shielded Tube Mount, catalog page F-8
2—809 Klystron Power Supply, catalog page F-10
3—303-A Slide Screw Tuner, catalog page B-14
4—1203 Waveguide Ferrite Isolator, catalog page A-21
5—535 Frequency Meter, catalog page D-12
6—195-B Precision Gauge Attenuator, catalog page A-5
7—UNKNOWN represented by a 140 Fixed Waveguide Attenuator, catalog page A-11
8—203-D Slotted Section, catalog page B-11
9—250-A Broadband Probe, catalog page B-12
10—277-A Standing Wave Amplifier, catalog page E-7
11—303-A Slide Screw Tuner, catalog page B-14
12—643 Waveguide Thermistor Mount, catalog page E-9
13—650-B Power Bridge, catalog page E-13
14—159-A Level Set Attenuator, catalog page A-17

MICROWAVE ENGINEERS-SCIENTISTS
Positions offering stimulating challenges with unlimited potential are now open at PRD. Please address all inquiries to Mr. A. E. Spruck, PRD, 202 Tillary Street, Brooklyn 1, New York.

Polytechnic Research and Development Co., Inc.

202 Tillary Street, Brooklyn 1, New York. Telephone: ULster 2-6800
West Coast Office: 2639 So. La Cienega Blvd., Los Angeles 34, California. Telephone: TExas 0-1940

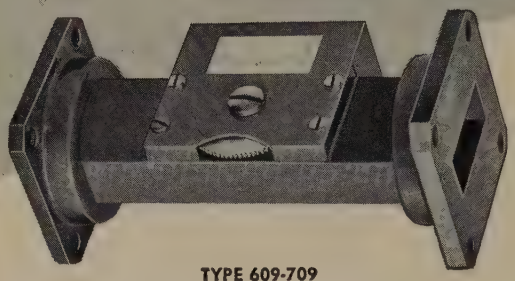
cial problems in attenuation and other related measurements? Contact our Applications Engineering Department.

NEW! **MINIATURE LIGHTWEIGHT**

ATTENUATORS

X AND KU BAND ALUMINUM

3½ OZ. WEIGHT



TYPE 609-709

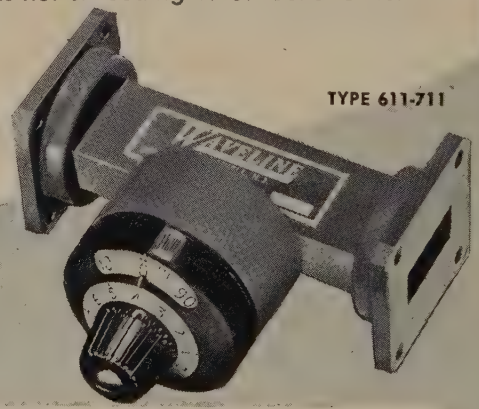
- SHIELDED
- RUGGED
- ACCURATE

TYPE 609-709 are NEW — A small, lightweight, rugged, highly accurate attenuator designed to provide accurate settings under conditions of shock and vibration. The dial can be securely locked. Finish is Iridite. Weight 3½ ounces.

Excellent shielding properties, low 1.15 maximum VSWR value, 0.3 db. maximum insertion loss and a range of 30 db. combine to provide exceptional electrical operation in a small unit.

TYPES 611-711 — The attenuation range of these units is 35 db. calibrated at 9.60 and 15.0 Kmc/Sec. Maximum insertion loss is 0.3 db. with VSWRs not exceeding 1.15. Construction is brass, gold plated.

Calibrated 5.0 db points centerband frequencies



TYPE 611-711

COMPLETE CATALOG AVAILABLE

Type	Unit Price	Frequency Range Kmc/Sec	Attenuation Range	Waveguide Type	Length Inches
609	$50.00	8.2-12.4	30 db	RG-67/U	3.50
709	50.00	12.4-18.0	30 db	RG-91/U-AL	3.50
611	75.00	8.2-12.4	35 db	RG-52/U	3.75
711	75.00	12.4-18.0	35 db	RG-52/U	4.00

LEADERS IN ATTENUATION DEVICES

WAVELINE INC.

CALDWELL, NEW JERSEY

Industry News

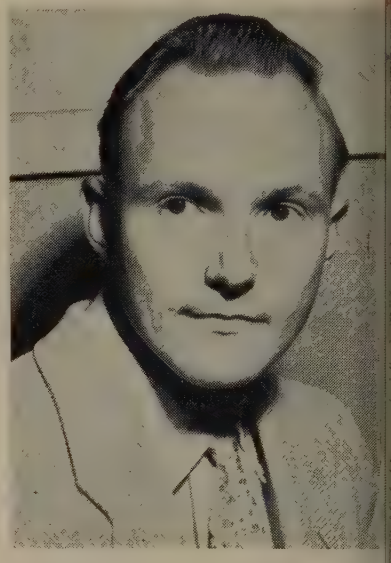
(*Continued from page 56*)

In 1953, Mr. Torgow returned to Microwave Research Institute and engaged in strip line and waveg filter development. He became leade the Component Research Section in 1

Mr. Torgow is a member of Sigma and a senior member of the IRE. He served on the IRE Admissions Com tee, and has been a member of the ministrative Committee of the New Chapter of the IRE Professional G on Microwave Theory and Techni for the past three years. He was ele to the vice-chairmanship of this organization for 1960. He is also a m ber of the IRE Committee on Ante and Waveguides and of the Edit Review Board of the IRE Transac on MTT.

— *mwj* —

TOWER CONSTRUCTION CO PROMOTES GOLDIE



Dean Goldie has been promote Special Projects Manager for Tower struction Co., according to an anno ment by company President, M. M. ensky.

Goldie, who has been with Towe seven years, was a field supervis government contracts and overseas ects. His new duties call for plan and supervising all of Tower's sp projects in this country and abroa

Goldie supervised the manufacture installation of both the Dew Line Tacan Towers, which are used at Air Force base as an aid to aircra landings.

Goldie is a graduate of the Univ of Tampa with a B.S. degree in m matics. He attended several tec radio and radar schools during a five tour with the Marine Corps. For a he served as an instructor at the M Corps' Radar School at Camp Pend California.

He is now working on two large eign projects that Tower will make lic in the near future.

— *mwj* —

w from Polarad

NTENNA ATTERN IICROWAVE ECEIVER

TRA-BROADBAND COVERAGE
2,000 to 75,000 mc in a single unit

- **External Mixer.** May be located at or near antenna, any distance up to 75 feet from receiver.
- **Flexible cable connects mixer to receiver.** Eliminates cumbersome rigid waveguide.
- **Internal electronic 1000 cps sweep** allows direct operation into any standard make AC antenna pattern recorder.
- **CW, AM, FM and pulse reception.**
- **Sensitivity.**
  2 kmc to 10 kmc....—85 dbm.
  10 kmc to 35 kmc....—80 dmb.
  35 kmc to 75 kmc....—70 dbm.
- **Linearity** maintained over 40 db dynamic range.

odel RW-T is another example of the versatility l well known Polarad Model R Microwave Re- r. The RW-T is excellent to measure antenna attern, minor lobes, front-to-back ratio, SWR ndwidth.

IFETIME SERVICE ALL POLARAD ISTRUMENTS

MAIL THIS CARD for specifications. Ask your nearest Polarad representative (in the Yellow Pages) for a copy of "Notes on Microwave Measurements."

LARAD ECTRONICS RPORATION

34th Street, Long Island City 1, N.Y.

entatives in principal cities.

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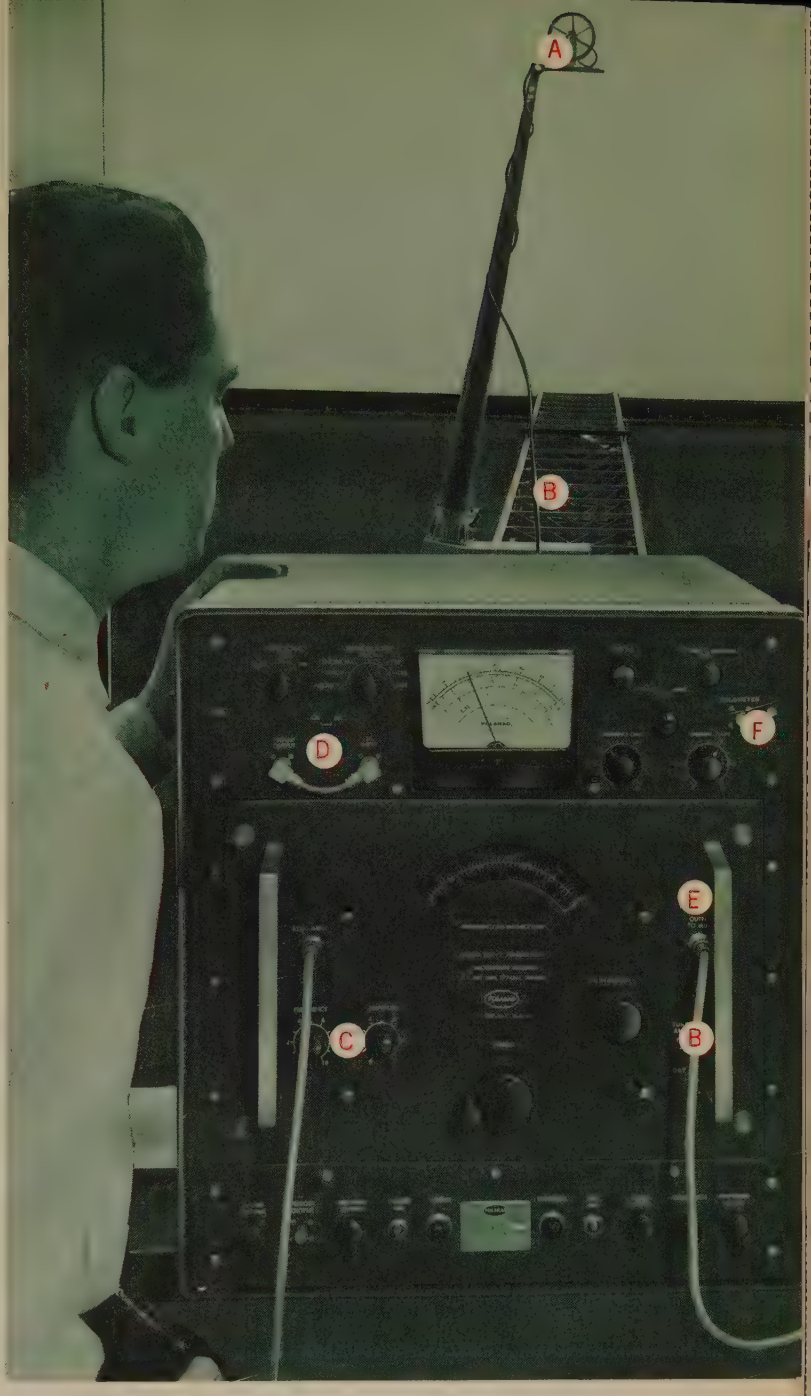

Model RW-T Microwave receiver being used to make antenna pattern measurements on Polarad range.

PDINM

POLARAD ELECTRONICS CORPORATION:

POLARAD PROVEN RELIABILITY

Please send me information and specifications on:

- ☐ Model RW-T Antenna Pattern Receiver
- ☐ Model KSS Microwave Power Source (see reverse side of page)

My application is_____

Name_____

Title_____ Dept._____

Company_____

Address_____

City_____ Zone_____ State_____

New from Polarad

COMPACT MICROWAVE POWER SOURCE

1,050 to 11,000 mc 4 PLUG-IN UNIT

Model KSS Power Source being used to make antenna pattern measurements on Polarad Antenna Range. Can also be used for minor lobes, front to back ratio, SWR and gain measurements.

The new Polarad Model KSS features an advanced modulator design that provides CW, FM and internal square wave (10 to 10,000 pps). External pulse capabilities permit rise times to 0.15 μsec. The unit has an adjustable attenuator and low incidental AM and FM at relatively high power.

(A) Basic unit (HU-4) includes modulator and power su
into which is plugged any one of four R-F tuning
(B) that cover the frequency range 1,050 to 11,00
Tuning units are equipped with UNI-DIAL control
automatically tunes klystron cavity with reflector volt

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DOUBLE RIDGED SLOTTED LINES

TORE N. ANDERSON

Assistant to President · FXR, Inc.

Long Island, New York

Associate

the microwave journal

A technique which has proven very useful for measurements in double ridge waveguides for commercial lines weather radar and ECM applications is shown in Figure 1. A special slotted section to fit the Hewlett-Packard 809B carriage is the basis with the exception that in order to avoid the problem of wave impedance discontinuities due to the conventional slot widths in the narrow ridge which is associated with the probe, such as the PRD-250A, it is necessary to go to a much smaller slot. In going to a much smaller slot, it is imperative that the probe be shielded in a coaxial arrangement to prevent the probe responding to slot modes which will give false indications.

The details for a suitable slot and probe extension which has been found satisfactory up to frequencies as high as 18 kmc is shown in Figure 1. The technique that has been used here is to use an extremely narrow slot; slot widths less than 16% of the total ridge width have been found satisfactory.

By keeping the probe shielded, the end of the probe extension should be just flush with the inside of the waveguide when mounted in the Hewlett-Packard carriage.

Care should be taken to insure that the probe is reasonably well centered in the probe extension to avoid short circuiting the probe when it is extended beyond its more normal use and for most ridge guide dimensions, the commercially available probes do have sufficient probe extension to allow for the use of the shield.

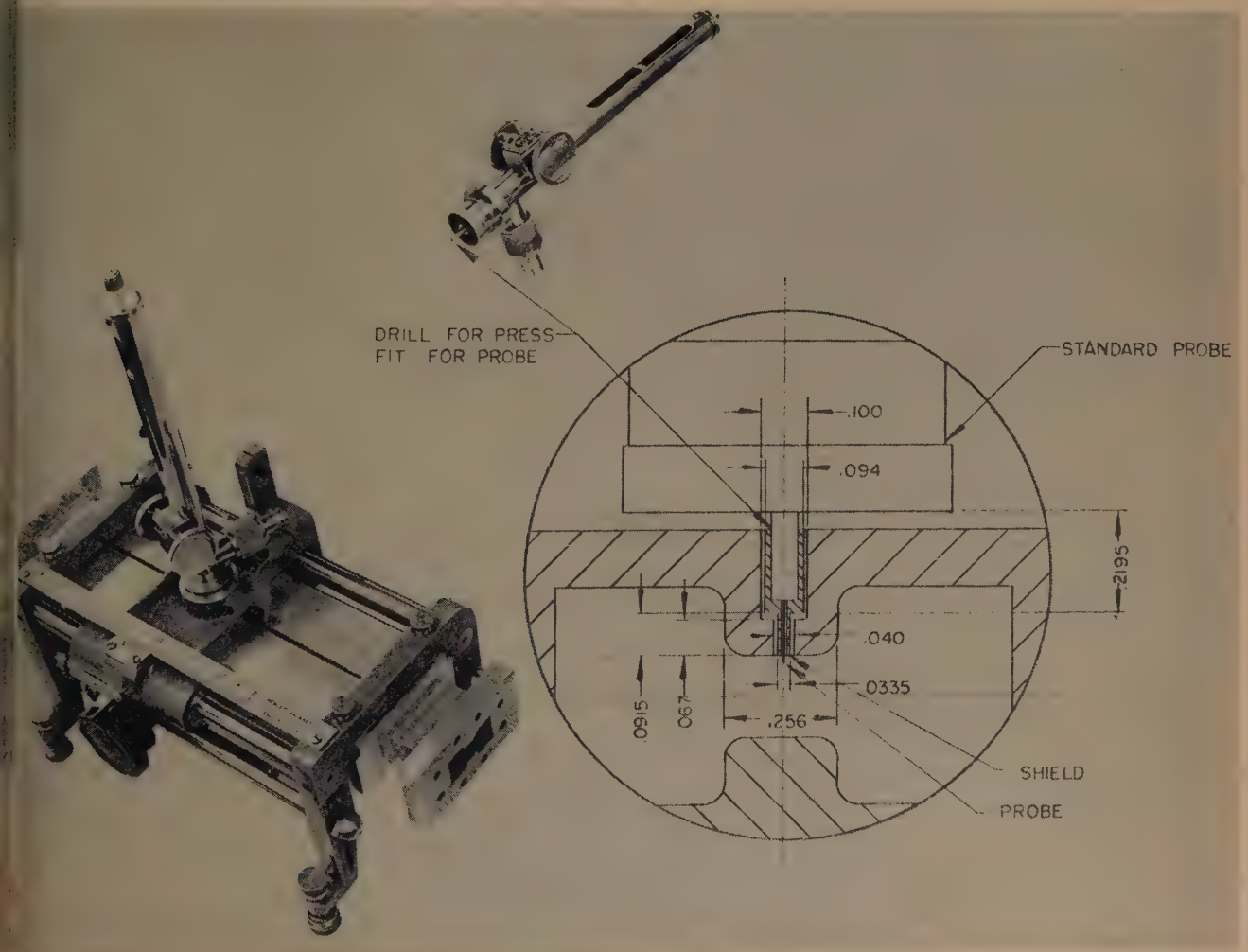
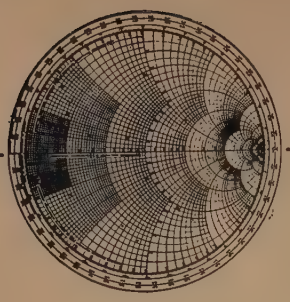


Figure 1 — Probe extension details for double ridge slotted lines.



the microwave journal

160 WARREN STREET, BOSTON 19, MASSACHUSETTS
HIghlands 5-6660

WILLIAM BAZZY
Publisher

Dear Reader:

Before you get too far involved with IRE show plans, let me take two minutes of your precious time for a brief note of thanks.

This, our 17th issue of *the microwave journal,* is the largest in our short history. Going to the four corners of the globe, it also has the largest circulation being mailed to over 23,000 VIP's, Engineers, Scientists, Sales and Purchasing people.

Recent readership studies by two independent microwave firms have revealed over 50% of all engineers surveyed read the journal regularly. In a short year and a half, "the journal" has shot from nowhere to the Number Three rating among a field of all-electronics publications.

Your confidence in us justifies our original confidence in you: give the engineer a book custom-made for him and he'll read it.

My original intent was to publish this letter of thanks in our IRE Issue next month but we have another announcement of interest to make at that time and my production staff refuses to allow me two pages in a special issue.

So, for now, on behalf of our editor, Ted Saad, and myself, let me thank you once again for making *the microwave journal* the resounding success it is. All we can promise you in return is bigger and better *mwj's* in the future.

Incidentally, if you're attending the IRE show in New York next month, please drop in on us at our suite in the Essex House around the corner from the Coliseum. Ted and I will be able to thank you personally over a cup of coffee.

Sincerely,

William Bazzy

Publisher

ustry News

V. N. MARTINOVITCH JOINS STAVID

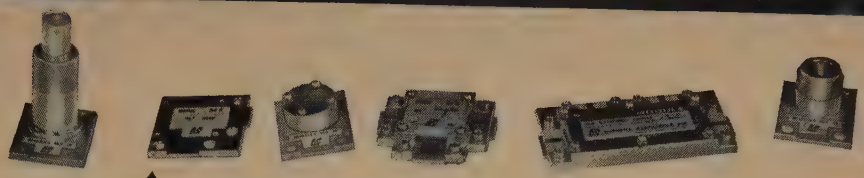
lim N. Martinovitch has joined
il as engineering consultant in high
r modulator and radar systems de-
il. He was formerly Senior Project
neer at FXR Incorporated, Wood-
New York, where he was engaged
e manufacture of custom-made test
ment and high power modulators,
n the development of high power
i radar transmitters. He received
.E.E. from the College of the City
ew York and is presently taking
ate courses toward a masters degree
. at Columbia University.
Martinovitch was also an electrical
n engineer at Vitro Corp. of America
rior to this was with Allied Pro-
. Walter Dorwin Teague Associates,
BM, all of New York City.

— *m w j* —

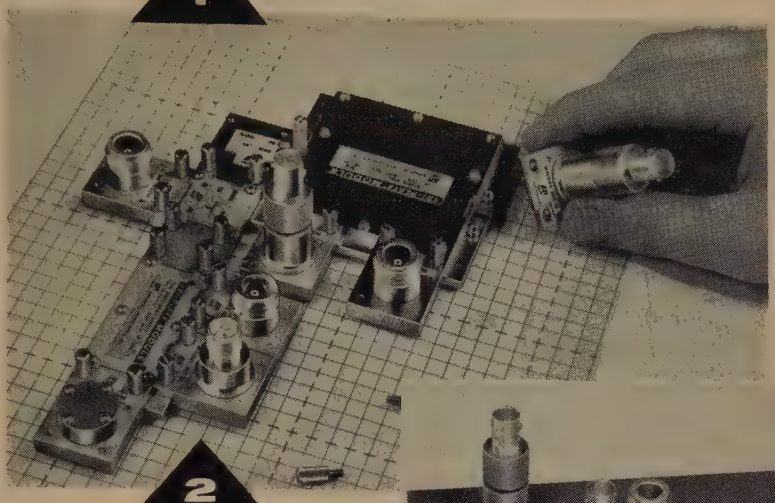
GABRIEL ELECTRONICS IN NEW FACILITY

re than 450 guests attended the
house ceremonies of Gabriel Elec-
s new 75,000 sq. ft. research, engi-
g, and manufacturing building at
, Mass.
guests, members of the electronics
ry, the press, radio and television
, and financial representatives were
cted on a guided tour which fea-
"Follow The Angel," signs, sym-
of the company name.
ton L. Yarbrough, president and
l manager of this division, wel-
John H. Briggs, president of The
el Company, Cleveland, Ohio, and
cted Mr. Briggs and his party on
st tour of the new facilities. Other
in the first tour included Robert
president of The Gabriel Division
eveland, Ohio; Thomas A. Cher-
company controller; and Howard
s, personnel director of The Ga-
Company.
owing the initial tour, other guests
taken on the tour of the impressive
ies for the engineering, manufac-
, and research and development of
nic equipment being produced for
vernment and private industry.

AS SIMPLE AS . . . 1 • 2 • 3



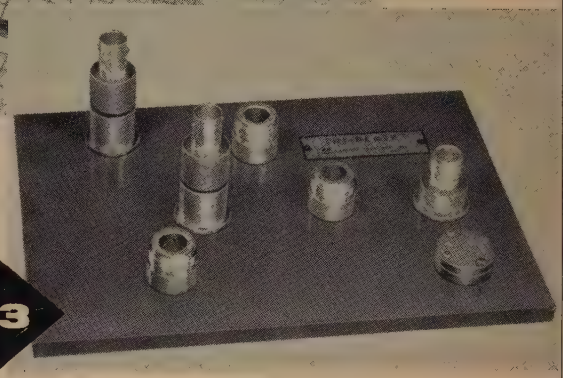
1 TRI-PLATE® MODULES



2 BREADBOARDED MICROWAVE CIRCUIT WITH MODULES

PRODUCTION PROTOTYPE STRIP TRANSMISSION LINE UNIT

3



HURDLE TIME AND COST BARRIERS WITH MICROWAVE STRIP TRANSMISSION MODULES

This balanced and single-ended mixer with common L. O. supply was breadboarded in just minutes with new Sanders TRI-PLATE Modules.

These revolutionary new Microwave Strip Transmission Line components with integral connectors permit you to go from design, to breadboard, to prototype with known characteristics without waste of time or effort.

Versatile, reusable TRI-PLATE building blocks eliminate the need for costly, time-consuming delays in breadboarding circuit designs for testing. Microwave circuits such as mixers, duplexers, and modulators can be actually "breadboard-designed" into working circuits in just minutes, with only a screwdriver.

To get all the facts on these new, on-the-shelf, TRI-PLATE Modules, write today.

® Sanders Associates, Inc.

Write for new bulletin on TRI-PLATE STRIP TRANSMISSION LINE MODULES.

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MICROWAVE Kearfott PRODUCTS

FERRITE ISOLATOR

The all new Model WD-2106 Octave S-Band Isolator marks a revolutionary advancement in the microwave field by permitting the use of only one isolator for a full octave frequency range instead of covering the band in increments using a number of isolators. Ideal for use in telemetry, radar systems and transponders, the new unit offers exceptional reliability, excellent isolation to insertion loss characteristics and compactness of design.

TYPICAL SPECIFICATIONS				
MODEL	FREQ. RANGE	ISOLATION	INSERTION LOSS	V.S.W.R.
WD-2106	**2.1-4.3 KMC**	**20 DB Min.**	**2.0 DB Max.**	**1.5 Max.**
W-568-3A-2	12.5-18.0 KMC	20 DB Min.	1.0 DB Max.	1.15 Max.
W-177-1K-1	9.5 KMC ± 100 MC	25 DB Min.	.7 DB Max.	1.15 Max.
W-277-3A-3	5.2-5.9 KMC	17 DB Min.	1.0 DB Max.	1.15 Max.
W-668-1A-2	8.5-9.6 KMC	10 DB Min.	0.4 DB Max.	1.10 Max.

THESE ARE ONLY A FEW OF THE MANY AVAILABLE MODELS

W-568-X W-177-X W-277-X W-668-X

KEARFOTT DIVISION

GENERAL PRECISION INC.

14844 OXNARD ST., VAN NUYS, CALIF.

ANDERSON NAMED AIDE TO FXR PRESIDENT

FXR, Inc., has announced the appoi ment of Tore N. Anderson as assistant Mr. Henry Feldmann, FXR Preside with overall supervision of the entire eration.

Mr. Anderson has been associated w Airtron, Inc., since 1948. In 1951, was appointed Vice-president and Ch Engineer of Airtron and elected to Board of Directors. In 1956 he w further appointed Director of Engine ing.

In 1954, he was appointed Chairman the EIA sub-committee on waveguide c nector standardization and in 1959, an international delegate participating meetings held in Ulm, Germany for preparation of international standards waveguide and waveguide connectors.

In 1959, Mr. Anderson was appoin consultant to the Department of Defe to the advisory group on Electron *D* and the Working Group on Transmiss Lines.

Mr. Anderson is an Associate mem of the Editorial Board of *the microw journal.*

— *m w j* —

NATIONAL COMPANY APPOINTS SMITH DIRECTOR OF FIELD LIAISON

The announcement of Perry C. Sm as Director of Field Liaison, Techn Liaison Division, was made by Jo H. Quick, President of National C pany, Inc., electronics firm for the e neering, development and manufac of communications and electronic syst

Mr. Smith, an inventor with twe five patents to his credit in fields electronics and electron optics, was viously Director of Customer Relat at Reeves Instrument Corp., Garden N.Y., where he was responsible for firm's advertising, marketing and pro planning operations.

LAX AWARDED BUCKLEY SOLID-STATE PHYSICS PRIZE

The Oliver E. Buckley Solid-State Physics prize of the erican Physical Society for 1960 was awarded to Dr. Ben- n Lax, Head of the Solid State Division of the Massachu- Institute of Technology's Lincoln Laboratory.

A scientist in many areas of physics of the solid state, Dr. was cited for the Buckley prize for his "fundamental con- utions in microwave and infrared spectroscopy of semicon- ors."

The Buckley prize amounting to $1,000, was presented to Lax at the annual dinner of the American Physical Society the American Association of Physics Teachers in the Hotel Yorker on January 29, 1960, by Dr. George E. Uhlenbeck e University of Michigan, President of the A.P.S.

The Buckley prize was established by Bell Telephone Lab- ories in honor of the late Dr. Oliver Ellsworth Buckley, ed chairman of the laboratories. It is made annually to the on adjudged to have made the most important contribution e advancement of knowledge in solid-state physics within five years immediately preceding the award.

Benjamin Lax adjusts resonance spectrometer at 2 milli- r wavelength for measurements on semiconductors at Lincoln Laboratory.

r. Lax joined the staff of the newly-formed Lincoln Lab- ry in October, 1951 as a member of the Solid State Group emphasis on work in semiconductors and the properties pplications of ferrites at microwave frequencies. He was d head of the Ferrites Group in May, 1953, and Leader e Solid State Physics Group in 1955, working on funda- l and applied physics of semiconductors and ferrites.

1957 Dr. Lax became Associate Head of the Communica- Division at Lincoln in charge of solid state physics in al laboratory groups, and was appointed Head of the State Division when it was established in 1957 in recog- n of his leadership in this field.

is interests and technical contributions include radar, wave discharges, plasma physics, ferrites, semiconductors, igh magnetic fields. In the five-year period, 1955-1959, Dr. as been the author or co-author of more than 30 technical es and has presented more than 40 prepared papers at ific meetings and symposia outside of the Lincoln Lab- ry.

r. Lax is a Fellow of the American Physical Society and mber of the Executive Committee of the Solid State Divi- the Solid State Advisory Panel of the Office of Naval rch. He is Associate Editor of the "Physical Review," the nal of Applied Physics" and *the microwave journal.* a member of the Society of Sigma Xi and is Chairman e 1961 International Conference on High Magnetic Fields, is now being organized.

e is married to the former Blossom Cohen of New York and they have two sons, Daniel and Robert. They reside estnut Hill, Mass.

DOUGLAS
MICROWAVE CO., Inc.
manufacturers of a complete variety of standard microwave test equipment and components.

is pleased to announce the addition of a new and complete line of

MACRA WAVE
(LARGE WAVE GUIDE) TEST EQUIPMENT AND COMPONENTS

which include the following:

These units will be supplied in the following EIA designated tubing sizes: WR77, WR975, WR1150, WR1500, WR1800, WR2100, WR2300.

adapters	signal samplers	loads	tees
test horns	crystal detector mounts	phase shifters	transitions
attenuators	terminations	slotted lines	tuners
bends		switches	wave meters
twists			

NEW! EXCLUSIVE!

DOUGLAS #105
WAVEGUIDE ADAPTER

Available for the first time commercially. It's bendable, twistable... it stretches, contracts, has unusually long life. Extremely useful for applications where expansions and/or contractions must be considered, or where continuous bending and twisting is a factor. Electrically superior to comparable units utilizing flexible waveguides. Covers 8,000-10,000 mcs. frequency range. Will bend 30°, twist 45°; will compress ⅛", expand ⅛" for each 3" of length. Available 3½", 8" and 12" long. Maximum VSWR for all of above: 1.08 to 1 or better throughout the band. The 8" and 12" units will permit increased twist and bend yet maintain same electrical characteristics.

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Think about facts! Think about the factors you expect in the job in which you work. Join a company where you have freedom, flexibility, future... Monogram Precision Industries, Inc.—Cascade Research Division, an expanding company with a growing backlog of orders for research and development and production!

Opportunities are now available for qualified microwave engineers with B.S.E.E. or M.S.E.E. or equivalent experience in top project and design positions. Consider the advantages of working with men who are pioneers in the microwave field and hold major patents ...in a company which is pushing beyond the boundaries of the state of the art. Think about working with production to watch your ideas take form from concept to completion. Work with management as an individual as well as a member of the team.

Join CASCADE RESEARCH — a company with room at the top.

In addition to top microwave project and design engineers, Cascade Research also needs chief draftsman, electronic technicians, and production planner.

If advancement is on your mind, write directly to Jerome S. Jaffe, Chief Engineer, Monogram Precision Industries, Inc.—Cascade Research Division, 5245 San Fernando Road, Los Angeles 39, California.

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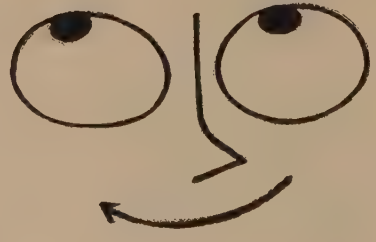
5245 SAN FERNANDO RD. WEST, LOS ANGELES 39, CALIF.
TELEPHONES: CHapman 5-8685 / CItrus 6-2575



DEVELOPERS & PRODUCERS OF MICROWAVE COMPONENTS & SYSTEMS

Industry News

EMERSON JOINS GOODRICH

Mr. W. H. Emerson joined the T foam Lab staff of the B. F. Goodr Sponge Products Division, to set in n tion research projects concerned with crowave absorbent materials. His wo will explore all possible means for velopment and expansion of the B. Goodrich Sponge Products microw business.

Mr. Emerson is a physicist and been associated with the electronics fi for 17 years. He is the author of seve articles which have appeared in vari technical journals, one of which he authored with Allan J. Simmons of Naval Research Lab which concerned self with Anechoic Chamber for mic waves.

Mr. Emerson was formerly with Naval Research Laboratories.

— *mwj* —

THOMAS M. LYONS NEW QUALITY CONTROL MANAGER AT NARDA MICROWAVE

Thomas M. Lyons, a member of American Society for Quality Control, been appointed Quality Control Mana of The Narda Microwave Corporati Mineola, Long Island, New York. announcing this appointment, William Bourke, president of Narda Microwa described Mr. Lyons' work as cover two broad categories of responsibiliti he will be concerned with the applicat of quality control and statistical anal to the inspection and test departments Narda, and he will also be respons for integrating results of all inspect tests and calibration studies with the c pany's engineering and manufactur processes in order to insure continu and constant improvement of quality. Lyons will report directly to Nar president.

Mr. Lyons is a graduate of the Merchant Marine Academy and also s ied Statistical Quality Control at Fa ingdale Agricultural Institute. Prior joining Narda, his seven years of exp ence in the quality control field inclu quality control managership of Amer Electronics' Taller and Cooper Pla and of Instrument Affiliates, Inc. Prio these assignments, he had both qua control engineering and supervisory perience at Servomechanisms Corpora and Reeves Instrument Corporation. is also a member of the Supervisory ecutives Institute of Nassau County.

— *mwj* —

LITERATURE . . .

SHORT-FORM MICROWAVE AN SPECIAL PURPOSE TUBES CATA ISSUED BY SYLVANIA

A new short-form catalog on m wave and special purpose tubes has made available by Sylvania Electric P ucts Inc.

The catalog lists principal elect

racteristics for more than 150 micro-e tubes and special purpose devices, rding to Thomas D. Fuller, market-manager of Sylvania's Special Tube rations.

he microwave components include eling-wave tubes, ferrite devices, mag-ons, and microwave diodes. Some of special purpose devices listed are de counter tubes, and trigger tubes. top frequency shown is 75 kilomega-es for a backward-wave oscillator. h power devices include X-band tun-magnetrons at 250 kilowatts.

rcle Reader Service Card 101

— *mwj* —

MICROWAVE DIRECTIONAL COUPLERS

six page technical brochure describ-Microwave Directional Coupler de- and operation is currently available n Waveline, Inc., Caldwell, New ey.

hirty types of couplers are illustrated their design and electrical perform-data are discussed. Mechanical di-sions are given for each of these stock s. Custom designed types are dis-ed and their functions outlined to-er with suggestions for submitting ification data for special assemblies.

rcle Reader Service Card 102

— *mwj* —

OWER SUPPLY REQUIREMENTS OF BWO TUBES"

ne latest issue of "PRD Reports," 6, No. 4, entitled "Power Supply irements of BWO Tubes" discusses voltage and modulation requirements ed to power backward wave oscil-s.

uthored jointly by Messrs. Stanley J. chard, and Martin J. Blickstein, of staff of the Brooklyn, N.Y. firm, the rt describes the theory and opera-of both M and O type tubes. The ionship between power output, fre-cy shift, and delay line current sta-y is graphically presented as a func-of various electrode voltages.

ne PRD 813 Universal BWO/TWT er Supply is discussed in detail and a ial listing of the Backward Wave llator tubes that the supply can op-is shown.

opies of "PRD Report" Vol. 6, No. offered free by the Polytechnic Re-h & Development Co., Inc.

rcle Reader Service Card 103

— *mwj* —

FILTRON OFFERS . FACILITIES BROCHURE

ltron Company, Inc., of Flushing, and Culver City, Calif. announces availability of a new descriptive hure outlining the company's ca-ies and capabilities in research, de-oment and systems engineering in field of radio-frequency interference urement, analysis and control.

The 20-page brochure also illustrates and describes production capabilities at the company's four facilities, describes the activities of its various operating divisions, and pictures a representative assortment of proprietary products, including r-f interference filters, delay lines, pulse components and specialty capacitors.

Circle Reader Service Card 104

— *mwj* —

MILLIMETER-WAVE COMPONENTS AND ANTENNAS ILLUSTRATED IN TWELVE-PAGE BROCHURE

A line of millimeter-wave components and antennas offered for the first time as standard items for immediate delivery is illustrated in catalog No. 160A, by the manufacturer, T.R.G., Inc., 9 Union Sq., Somerville 43, Mass.

Complete specifications are included on ferrite components such as Isolators, Attenuators, Circulators, and Switches, as well as Hybrid Ring Mixers and Millimeter-Wave Antennas. Additional millimeter-wave components listed allow for complete systems design in the 60-75 KMC V-Band.

Circle Reader Service Card 105

— *mwj* —

FARWELL BROCHURE

Farwell Metal Fabricating, 75 West Fairfield Ave., Saint Paul, Minnesota is offering a six-page brochure demonstrating the firm's capabilities in precision metal manufacturing.

Farwell offers a complete custom or contract metal manufacturing service for the electronics, missile, aircraft and nuclear fields. The firm has been granted Secret Facility Security clearance, and their quality control program has been approved under MIL-Q-5923C.

Circle Reader Service Card 106

— *mwj* —

SYLVANIA MICROWAVE DIODE BOOKLET

A new technical booklet on microwave diodes has been made available by Sylvania Electric Products Inc., it has been announced by Roger A. Swanson, product sales manager of microwave diodes for the company's Semiconductor Division.

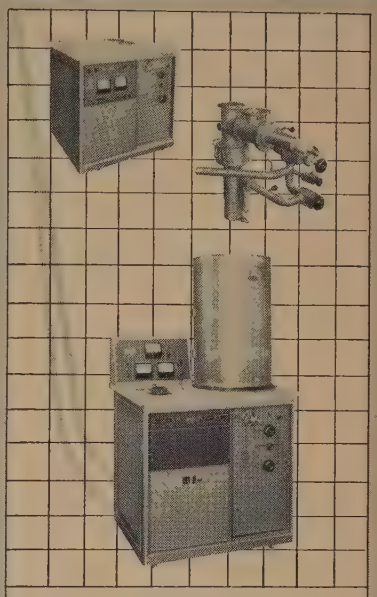
The 12-page booklet contains complete electrical and mechanical data on all microwave diodes manufactured by Sylvania as well as a replacement guide to nearly 200 widely-used diode types.

Mr. Swanson said that the new booklet contains technical information on the company's recently announced Micro-Min line, smallest microwave diodes in the industry. He said Micro-Min diodes create an "almost infinite number of new design possibilities" for applications up to 150-degrees centigrade.

Circle Reader Service Card 107

— *mwj* —

You're guaranteed 10^{-6} mm Hg *fast* with . . .



THE MODULAR "400" SERIES 4" VACUUM SYSTEMS & EVAPORATORS

GUARANTEED PERFORMANCE:

5 x 10^{-6} in 45 sec.
Less than 5 x 10^{-7} ultimate (blanked port)

5 x 10^{-6} in 4 min.
Less than 10^{-6} ultimate (18" x 30" Bell Jar)

MODULAR CONSTRUCTION:
Buy exactly what you need, from basic plumbing to complete Evaporators and Bakeout Systems. Incorporate additional equipment as your requirements grow.

TROUBLE-FREE PERFORMANCE:
Each VE-400 System undergoes a full week (168 hrs.) of test run and inspection before shipment.

FREE "400" SERIES BROCHURE contains complete performance data and design specifications on the 4" building block components and modular systems. Write Department A-1436.

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HIGH VACUUM & LEAK DETECTION EQUIPMENT

Visit Booth 3001-3002, IRE Show, N.Y.C.

New Products

ULTEK HIGH-VACUUM PUMP

A new leaflet describes the Series 150 Electronic High-Vacuum Pumps available under the trade name UlteVac. This new publication illustrates the Model 150 together with corresponding power supply which operates the units in general laboratory application as well as vacuum-tube processing and thin-film work. A calibration curve is included with pump current plotted against pumping pressures. The pump is manufactured by the ULTEK Corp., 920 Commercial Street, Palo Alto, California.

Circle Reader Service Card 108

— mwj —

A NEW MICROWAVE SWITCH FROM TUCOR

The Beacotron tube is a new and significant development by Tucor, Inc., South Norwalk, Conn. a leading manufacturer of microwave components. This new device is a radically different microwave component which now permits simplified and unique control possibilities previously difficult to achieve.

The Beacotron is essentially a microwave energy coupler employing an electron beam for the coupling medium. The Beacotron tube is unique, however, in that the coefficient of coupling is smoothly variable over a broad range. Up to 60 db isolation between input and output can be readily obtained merely by adjusting the potential on a switch electrode. With the beam adjusted for full coupling, gain slightly greater than unity is possible. This is due to an interaction effect between the beam and the beam couplers which results in a small amount of positive gain. At full coupling, all signals within the beamwidth capabilities of the Beacotron will be coupled from input to output without attenuation.

In general, the amount of power which may be coupled is limited to approximately 20% of the dc power in the beam, although under certain conditions this power can be raised to as much as 50% of the beam power. Various designs are now available for application at frequencies ranging from VHF through the 10,000 megacycle band.

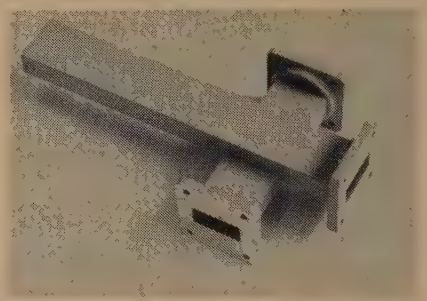
In applications where r-f power must be switched rapidly, the Beacotron offers many distinct advantages over present cumbersome and costly methods. The response time of the Beacotron is in the order of one milli-microsecond. High-speed switching can be accomplished with minimum disturbance to the transmission line, since both input and output coupling circuits are terminated in the characteristic impedance of the line itself. Therefore, a matched impedance is presented to both input and output circuits at all times, regardless of whether the switch is on or off.

Another interesting feature of the Beacotron is the fact that the impedance of the switch electrode is extremely high, thereby ensuring excellent switching efficiency.

Circle Reader Service Card 109

— mwj —

NEW RDC CROSS-GUIDE COUPLERS HAVE REDUCED COUPLING DEVIATION



Reduced coupling deviation is a feature of two new cross-guide couplers which have been added to the line of couplers manufactured by the Radar Design Corp., Syracuse, N.Y.

Both couplers operate in the frequency range 7-10 kmc with a maximum coupling deviation over the band of $\pm$ 1 db, and are available with nominal coupling values of 20 or 30 db.

Model RDC-710 has one arm terminated in a matched load while Model RDC-680 does not have its fourth arm terminated.

Specifications for both models are as follows:

Average Coupling — Nominal $\pm$ 0.5 db; directivity — 18 db minimum; VSWR — 1.05 maximum; maximum coupling deviation — $\pm$ 1 db maximum; connectors — waveguide cover flanges; delivery — 10 days.

A catalog sheet describing both couplers is available upon request.

Circle Reader Service Card 110

— mwj —

JERROLD PRODUCES RUGGED NEW COAXIAL SWITCH

A new manually operated rotary coaxial switch has been placed into production by Jerrold Electronics Corp., Philadelphia, Pennsylvania.

Designated as Model CS-250, the new switch is a ruggedly-built four termin two position transfer switch coaxia mounted in a rugged die cast me frame. Its dual wiping, self align switch contacts are silver, and mounted in Kel-F dielectric.

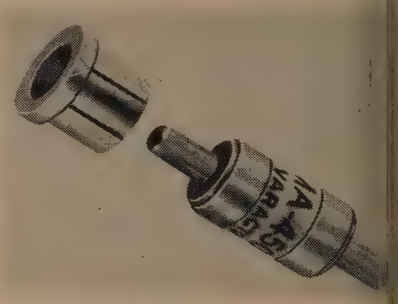
The CS-250 is designed to operate the frequency range 0 to 1000 mc wit maximum VSWR of 1.1 up to 500 and 1.2 up to 1000 mc. Insertion l over the range is less than 0.1 db, a isolation between the open and clo circuits is 58 db at 100 mc and 40 at 1000 mc.

Available with 50-ohm BNC conn tors, the CS-250 lists at $19.60.

Circle Reader Service Card 11

— mwj —

HERMETICALLY SEALED VARACT DIODES



A new series of hermetically sealed con Varactor diodes has been introdu by Microwave Associates, Inc., of Burl ton, Massachusetts.

These new diodes, designated MA-4 through MA-450E, feature reversible larity by means of a base adaptor supp with each diode.

The new diodes are mechanically rug for maximum reliability. Cartridge sh capacitance, measured at 100 kilocycles about 0.4 micromicrofarads. Series inductance is less than 10^{-9} henries. Po dissipation rating ranges between 300 m watts for lowest cutoff types to 150 m watts for highest cutoff types.

The MA-450 diodes conform to MIL dimensions for cartridge style diodes as the 1N21 and 1N23 types.

MA-450 varactors are intended for as the amplifying element in low-n parametric amplifiers; balanced, single band modulators; harmonic genera where they replace point contact dio sub-harmonic generators (Parametro r-f limiters; and in many other specia applications.

Circle Reader Service Card 1

— mwj —

his man is using ie industry's ost advanced wept microwave scillator

now available from ALFRED ELECTRONICS

No other sweeping oscillators offer as many solid advantages as Alfred Electronics' new series 620 models, built by the industry's leading manufacturer of high quality, broadband microwave instruments. Note these features:

★ **Six models, covering 1 to 18 kmc.** Broadest frequency range available. Electronic sweep of RF output, or extremely stable CW operation.

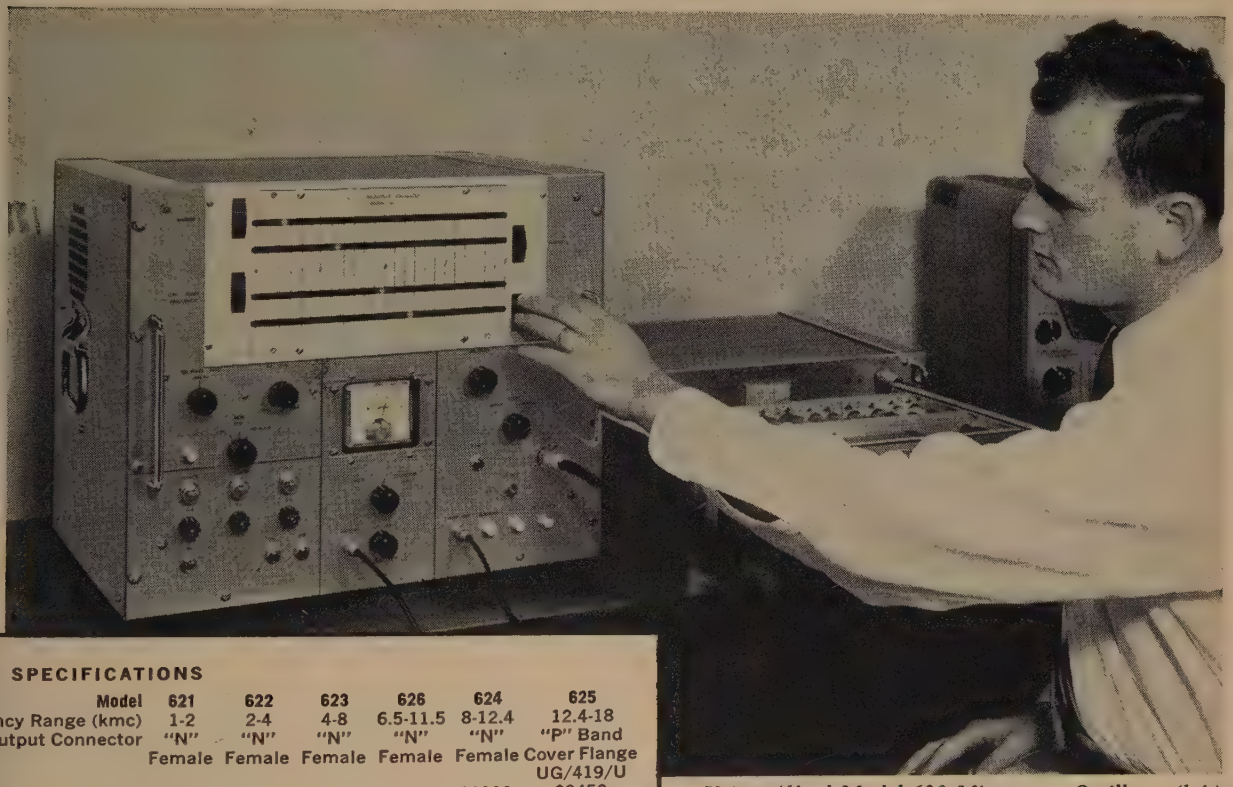
★ **Linear frequency sweep coverage** over all or part of each band for rapid evaluation of reflection coefficient, gain, attenuation and other network transfer characteristics.

★ **Two adjustable frequency markers** for convenient calibration of oscilloscopes or recorders. Markers save valuable test time by indicating either band limits or intermediate frequency values. An exclusive Alfred feature on all models.

★ **0.5 microseconds rise and fall** response to AM—equivalent to a 2 megacycle band pass. Another exclusive Alfred feature.

★ **Quick Look readout.** See frequency range, markers and sweep time at a glance. No cumbersome calculating.

★ **Fast sweep** for flicker-free oscilloscope presentation; slow sweep for mechanical recorder operation.



Using Alfred Model 623 Microwave Oscillator (left) to test small signal and saturation gain of Model 503 Traveling Wave Tube Amplifier. Microwave Leveler, Alfred Model 704, holds power output from oscillator constant within ±1 db.

RIEF SPECIFICATIONS

Model	621	622	623	626	624	625
equency Range (kmc)	1-2	2-4	4-8	6.5-11.5	8-12.4	12.4-18
RF Output Connector	"N" Female	"N" Female	"N" Female	"N" Female	"N" Female	"P" Band Cover Flange UG/419/U
Prices	$3090	$2990	$2890	$2990	$2890	$3450

NERAL

EQUENCY CONTROL: Continuously adtable with direct calibrated dial. ibration accuracy, 1%.

WER OUTPUT (minimum): 10 mw. Conuously adjustable from zero to maxim.

VR (maximum): 2:1.

EEP

ELECTOR: Recurrent sweep, single sweep, CW, and external on panel witch.

CONTROL: Single sweep, triggered by anel button, or external positive go- ng signal 20 volts or greater.

SWEEP WIDTH: Continuously adjustable from 0 to any part of entire frequency range.

TIME: 100 to .01 seconds.

MONITOR OUTPUT: Positive linear sawtooth, 45 volts peak; Blanking out, 75 volts negative.

EXTERNAL SWEEP: 200 volts gives full sweep width.

AMPLITUDE MODULATION

INTERNAL SQUARE WAVE: RF output alternately 0 and unmodulated CW value. Frequency 800 to 1200 cps.

EXTERNAL: 30 volts maximum signal increases RF output from 0 to maximum.

POWER INPUT: 105 to 125 volts; 60 cps.

Write us for complete details of these new oscillators. We'll also send you our new short form catalog, which describes Alfred's complete line of packaged traveling wave tube amplifiers. Address Dept. 68-2.

ALFRED ELECTRONICS

897 COMMERCIAL STREET
PALO ALTO, CALIFORNIA

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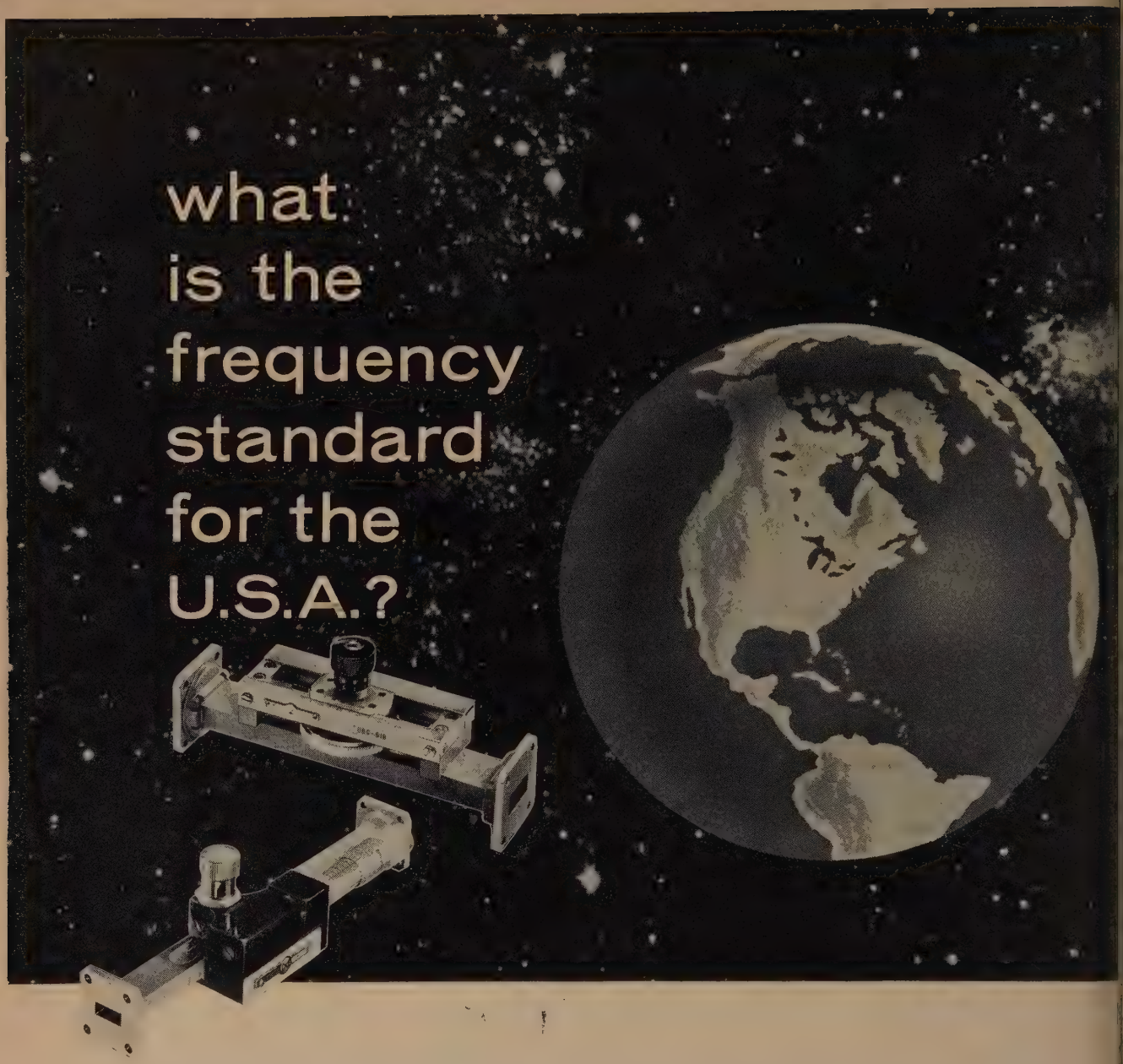


ANSWER: By act of Congress, the U.S. Bureau of Standards determines the primary standard, based on the revolution of the earth. All DeMornay-Bonardi microwave instruments are calibrated at frequencies which are verified by our secondary standard, which, in turn, is periodically calibrated, point for point, by the U.S. Bureau of Standards.

One way to properly match a microwave transmission line is by using a D-B Stub Tuner to reduce mismatch losses and utilize the total energy available.

D-B stub tuners in the 2.6 to 18 KMC range have a new scale and vernier that gives precise resettability in longitudinal travel. A new micrometer scale on the probe measures penetration with very high accuracy.

Probe wobble is eliminated, and no resonances can occur under any conditions. You can correct VSWR as high as 20:1 with amazing accuracy (1.02). You can tune with precision... reset to original settings with certainty that phase and magnitude have been duplicated.

Ditto for higher frequencies. D-B tuners in the 18 to 90 KMC range are not simply scaled-down units—they're engineered for ultramicrowave® use. All the above features are available, plus micrometer positioning which provides readability to .0001".

Write for data sheets—they detail all features, applications, dimensions, sizes. Bulletin DB-919.

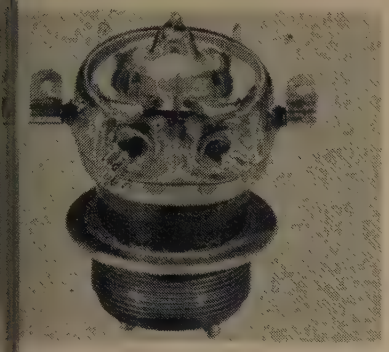
DE MORNAY BONARDI®

780 SOUTH ARROYO PARKWAY • PASADENA, CALIFORNIA

Circle Reader Service Card 43

MINIATURE VACUUM RELAY

nnings Radio Manufacturing Corp. unces their new RB7B vacuum trans- elay that offers the highest voltage g obtainable anywhere in a minia- relay of this size. Where space and ht is critical this new relay will be cularly effective in many relatively voltage applications involving an- switching, pulse forming networks, similar r-f and dc circuits.



e two pole double throw RB7B ures only 1-9/16" overall but has a operating voltage of 4 kv at 60 and 2.5 dv at 16 mc. It has a con- us current rating of 6 amps at 60 and 3 amps at 16 mc.

e small physical size and high volt- rating are possible because of the m dielectric and sapphire actuating Sealed rocker contacts provide heavy ct pressure and resistance to vibra- nd shock. Contact resistance is low remains low due to absence of con- ontamination.

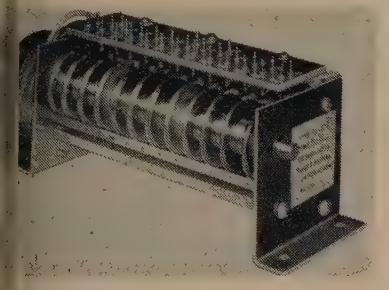
movable actuating coils are available 6.5 vdc or 115 vdc operation.

cle Reader Service Card 113

— m w j —

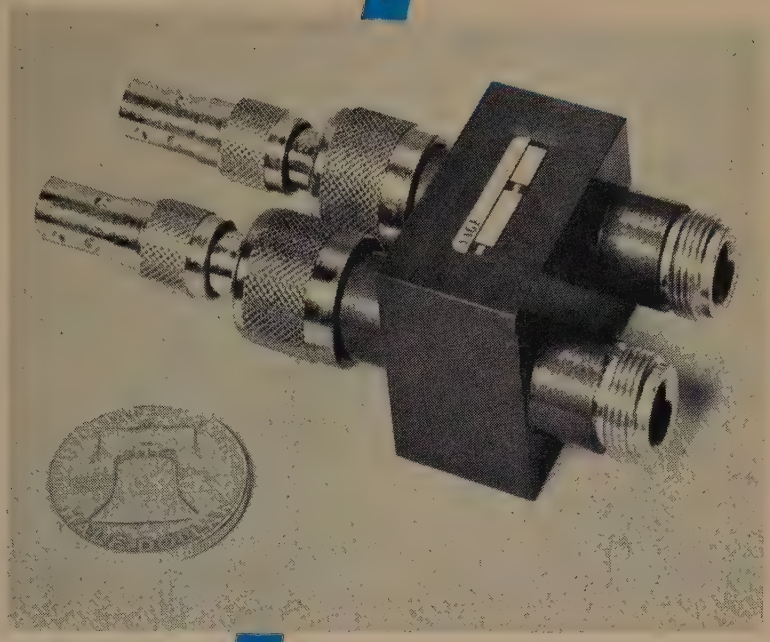
PROGRAM TIMER FOR GSE

he HYS Repeat Cycle Timer manu- ed by the Eagle Signal Company, e, Ill. measures only 2¼" x 2¼" but contains 12 SPDT independently table and removable load switches. r operates on 115 volt, 60 cycle



r. Time cycle is 90 seconds. Built round Support Equipment, the timer withstand vibration of 0.060" double tude displacement from 5 to 55 cps hock of 30 G's for 11 milliseconds. rticular interest are the extra large (1⅛" O.D.) which allow time gs with an accuracy of 1% or .

cle Reader Service Card 114



MIXERS

SPURIOUS REJECTION?	L. O. SUPPRESSION?
MICROWAVE IF?	LOW CAPACITY OUTPUT?
SINGLE ENDED?	BALANCED?
LOW VSWR?	LOW NOISE?
NARROW BAND?	BROAD BAND?
COMPACT?	DEVELOPMENT?
SMALL QUANTITY?	PRODUCTION?
HALF DOLLAR?	WHO?

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TWO NEW CERAMIC-METAL PENCIL TUBES BY RCA FOR MISSILE-GUIDANCE AND SATELLITE-COMMUNICATIONS SYSTEMS

Two new pencil-thin ceramic-metal electron tubes, 1½ inches long, were introduced recently by the RCA Electron Tube Division, Harrison, New Jersey.

The tubes, RCA-7552 and RCA-7554 high-mu triodes, are especially designed for UHF service in portable field equipment, missile-guidance systems, and satellite-communication applications.

Mr. C. E. Burnett, Manager, Industrial Tube Products Department states that, "the space-saving pencil-tube design enables the construction of extremely compact electronic equipment. Pencil-tube design incorporating ceramic-metal construction permits a smaller, more sturdy tube which can operate at plate-seal temperatures up to 225°C. Evidence indicates that this construction has greater endurance to nuclear radiation than glass-metal construction."

Additional design features of the 7552 and 7554 include: large cathode area as compared with comparable planar types; fast warm-up-time — only 12 seconds to reach 90% of direct operating plate current; and excellent thermal stability.

Both types can be operated up to altitudes of 100,000 feet without pressurization, and have a maximum plate dissipation of 2.5 watts. The 7552 is designed for class A r-f amplifier service up to 1000 mc and above; the 7554 for class C operation as an oscillator, r-f amplifier, and frequency multiplier up to 3000 mc and above.

Circle Reader Service Card 115

— m w j —

NEW VHF SILICON MESA TRANSISTORS INTRODUCED BY TEXAS INSTRUMENTS

Texas Instruments Incorporated has announced that two new silicon mesa transistors featuring high power combined with high frequency are immediately available in production quantities through all company sales offices and authorized distributors.

The new TI silicon mesa transistors, the 2N715 and 2N716, are capable of a guaranteed minimum power output of 500 milliwatts at 70 megacycles. These devices will deliver approximately 50 milliwatts at 200 megacycles. The inherent high-dissipation capabilities of transistors produced by the TI diffusion process permit both the 2N715 and 2N716 to be packaged in the subminiature JEDEC-outline TO-18 case.

Both new TI mesa transistors have a guaranteed beta spread of 10 to 50 and a collector reverse voltage of 50 and 70 volts (for the 2N715 and 2N716 spectively). Collector reverse current 25°C is 0.5 microamps maximum and microamps maximum at 150°C. Temp ture limits are at —65°C and 175°C

The TI 2N715 and 2N716 featur high degree of uniformity and reliab made possible by the diffusion produc process. To further assure the hig possible reliability, all connections cluding the can-to-header joint are complished by thermocompression bo ing — completely eliminating solder flux.

Because of their maximum reliabi the 2N715 and 2N716 are especially suited to application in advanced sp exploration and missile telemete equipment, communications equipme video amplifiers and non-satura switching circuitry.

Circle Reader Service Card 1

— m w j —

REMOTE TUNED SIGNAL SOUR ANNOUNCED

The Model SS 305 Remote Tuned nal Source is now available from Sc tific-Atlanta, Inc., Georgia manufact of microwave and antenna instrume tion.

The new instrument is primarily signed to provide a source of rem tunable r-f power for antenna pa ranges. Suited to remote tuning, co and band switching at distances of than a mile, the Model SS 305 c the frequency range from 50 to 200 calibrated to an accuracy of ± 2 The instrument provides a minimun power output of 80 milliwatts acros impedance of 50 ohms. This output be sine or square wave modulated.

A convenient servo null lamp indi completion of tuning. The new Re Tuned Signal Source can be returne a given frequency with an accurac ± 0.5%.

All three sub-units are mounte standard 19" wide rack mounting pa The remote tuning unit and the p supply and servo units are mounte 5¼" high panels. The r-f oscillator is mounted on a 12¼ panel. Net w is 105 pounds.

Price of the Model SS 305 Re Tuned Signal Source is $3,850 f.o.b lanta, Georgia.

Circle Reader Service Card

— m w j —

PATENT FIRM OFFERS UNIQ PATENT SERVICE

Industrial Patent Research Com Columbus, Ohio is now offering a u service especially tailored for the agement and research and develop staffs of firms engaged in electr microwaves, and related fields. The ice entails the reduction of technica ents to easily understood digests of principles. These short summari patents, free from legal terminolog

- Balance inherently independent of frequency
- Handles high power
- Constant coupling in both magnitude and phase over the frequency range with equal loads

$275.00

Type	Frequency range	Residual unbalance (isolation)	Price
1102	1600-2400 mc	greater than - 40 db	$275.00
1104	2400-3600 mc	greater than - 34 db	$275.00

Type 1104-S Hybrid for use over the frequency range 2200-5000 megacycles is also available. It has the same low residual unbalance but a higher SWR.

Write for complete information on AMCI Transmission Line Hybrids

AMCI
ANTENNA SYSTEMS — COMPONENTS — AIR NAVIGATION AIDS — INSTRUMENTS
ALFORD *Manufacturing Company*
299 ATLANTIC AVE., BOSTON, MASS.

ndant detail, can be scanned and un-ood in a few minutes by scientific nnel. Thus, personnel are kept e of new developments revealed in ts, obtaining maximum useful in-ation in minimum time.

ents of this service can assimilate 100 or more patents a week in less than is required to review a single hy patent, when provided with these se patent analyses. The analyses are saving research tools which can e significant cost savings.

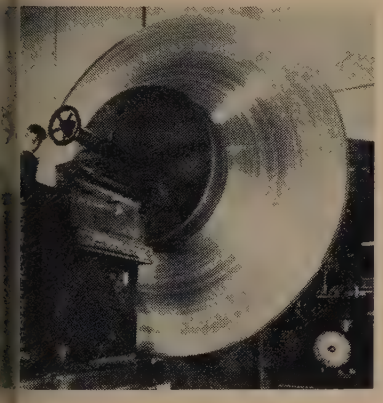
ents to be analyzed are provided e client to IPR which then prepares nalysis in accordance with an agree-established between the two com-s. These concise extract-abstracts are distributed to designated personnel e client company. The latter are kept ptly and permanently informed of icant developments, past and pres-n their fields of interest.

more complete description of the es offered by IPR, examples of t analysis in typical fields of inter-nd further information are available quest.

cle Reader Service Card 118

— mwj —

NEW APPLICATIONS OF METAL SPINNING



dings just released reveal unparal-new applications for the exclusive orn metal forming process devel-by the C. W. Torngren Company, of Somerville, Massachusetts. This s is responsible for an economical of producing symmetrical metal s for use in the fields of experi-l and production work in rocketry, onics, and communications.

Mecatorn process is used for pro-n of the nose-cone of the Titan M), combustion chamber cap and ead for the Minute Man missile, owls for supersonic fighters, para-reflectors for telemetering antennas, ead seals for Atomic Submarines, ountless other space-missile compo-

Mecatorn process is the automatic ation of hydraulic pressure to the t method of metal spinning. With pressures upward of 200,000 psi, incremental plastic deformation of metals such as 5/8" stainless steel and 3/4" aluminum can be achieved. Either hot or cold spinning can be applied to pieces up to 16' in diameter — a size impossible by any other process.

For further details write for free literature.

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— mwj —

PRECISION FREQUENCY DECADE FOR MICROWAVES

Very accurate calibration of microwave equipment is greatly simplified by the new Type FD3 Frequency Decade manufactured by Schomandl K. G. of Munich, Germany, and imported by Electronic Applications, Inc., Stamford, Conn.

The FD3 generates frequencies at full crystal accuracy in a fundamental range of 300 to 1000 mcs, at intervals of 100 kcs. Intermediate values are continuously tunable with a small inaccuracy of ± 300 cps. Auxiliary equipment may be used to reduce the synchronization interval to 100 cps, and the continuous tuning error to 0.1 cps.

Using a harmonic generator, the measuring range of the FD3 as a *generator* is 300 mcs to 10,000 mcs. When used as a *frequency meter* (by forming harmonics of unknown frequencies from 30 to 300 mcs; by forming harmonics of oscillator for measurement in the 1000 mcs to 10,000 mcs range) the measuring range is 30 mcs to 10,000 mcs.

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— mwj —

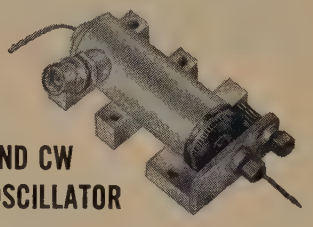
TWO NEW KLYSTRON POWER AMPLIFIERS FROM S.E.C.

Two new klystron power amplifiers, designed for both military and industrial applications, have been developed by Sierra Electronic Corporation, a division of Philco Corporation.

NEW!

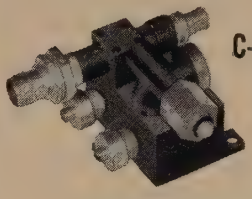
C-Band *System-Tested*
MICROWAVE COMPONENTS

Engineered to meet complete Military Missile Specifications



C-BAND CW OSCILLATOR

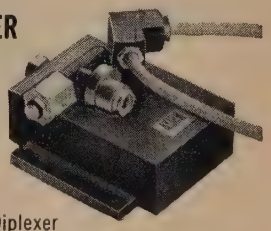
- Minimum 3 mw Power Output
- Adjustable Tuning over a range of 500 mc
- Tube—Triode GZ 5139
- Miniaturized—only 4" long, 1¾" wide, 1¼" high (excluding connector)



C-BAND BEACON FRONT END ASSEMBLY

- An exceptionally compact, lightweight unit, featuring low loss and ultra-high selectivity.
- Extremely small—only 2½" x 2½" x 2"

C-BAND FILTER MIXER DIPLEXER



- Mixer and Diplexer (non-tunable) operate as an integral part of the Filter
- Unit features minimum Insertion Loss, Rejection Bandwidth and Input VSWR
- Tuning Range—minimum 500 mc

WRITE for prices and delivery.

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ACF INDUSTRIES INCORPORATED
AVION ACF AVION DIVISION
11 Park Place, Paramus, N. J.

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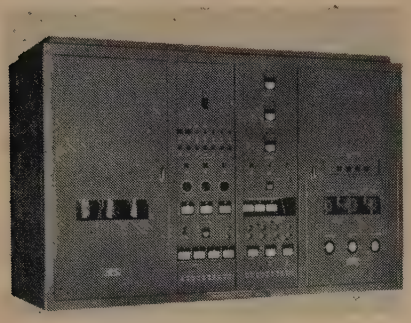
One of the amplifiers, Model 216A, has a power output of 10 kilowatts, while the Model 217A is a 1-kilowatt unit. The amplifiers, which employ four cavity,



water-cooled klystron tubes, are particularly useful in scatter communication systems, space programs and high power point-to-point data transmission systems.

Both units can be continuously tuned over the frequency range 1700 to 2400 mc. When operated as broadband amplifiers, they provide a minimum gain exceeding 40 db.

The 1-kilowatt amplifier, self-contained in one cabinet, has a maximum frequency bandwidth of 15 megacycles at the ½ power points. It is a compact unit with outside dimensions of 84″ high, 44½″ wide and 42″ deep.

With the exception of its heat exchanger, the 10-kilowatt amplifier is completely contained in three connected cabinets. Its frequency bandwidth is 18 megacycles at the ½ power points.

Operating controls on both amplifiers are arranged for maximum convenience and efficiency.

Further information is available on request.

Circle Reader Service Card 121

— m w j —

HRB-SINGER BANDPASS AMPLIFIER-MULTICOUPLER OFFERS 30-300 MEGACYCLE RANGE

A new distributed bandpass amplifier which provides optimum low noise capabilities and a flat frequency response of from 30 to 300 megacycles has been introduced by HRB-Singer, Inc., a unit of The Singer Military Products Division, N.Y.C.

The 30-300 mc range is obtained from four separate outputs with a minimum input-to-output isolation of 60 db and an average of 30 db isolation between any output.

The HRB-Singer Amplifier-Multic ler (Model 330-M4) is basically a tributed bandpass amplifier couple parallel grounded grid amplifier st having individual outputs. The amp includes an input network which m possible the optimum low noise bilities and flat response.

An important feature is the pa connection of the amplifier's six tubes. With this innovation failur several tubes will not seriously l the instrument's performance.

The amplifier, constructed with miniature components and printed ci techniques, presents a lightweight, ru package.

The multicoupler case is designe use in a rack panel installation o bench experimental testing purposes. units are shipped ready for use i rack panel installation and can b moved for bench use simply by tu the Dzus fasteners on the front p Identical panel markings are on the panel.

Other specifications of Model 33 are: r-f Gain, 6 db; Noise figure, average; Input impedance, 50 ohms inal; Output impedance, 50 ohms inal; Power requirement, 117 v. a amp; Size, 5¼ x 5¼ in. with sta 19-in. relay rack panel; Size of P Supply, 8¾ x 9¼ in. with standar in. relay rack panel.

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VLETT-PACKARD OFFERS NEW PRECISION ATTENUATORS

series of broadband precision atten-
s which remain accurately calibrated
dless of humidity, temperature, or
are now available from Hewlett-
rd Company.

e attenuators, Model 372, are offered
waveguide sizes covering the band
o 18 kmc, with nominal attenua-
of 10 or 20 db. Attenuation is in-
nt with time and ambient condi-
according to the manufacturer be-
it depends neither on the position
r power absorbed by, resistive cards
nes. Instead, attenuation is a func-
of the coupling-hole array between
permanently-joined waveguide sec-
— the same principle employed in
ett-Packard directional couplers.

enuation accuracy of the Model 372
uators averages better than $\pm$ 0.4
om nominal. Variation across the
is less than $\pm$ 0.5 db from mean.

ce there are no protrusions into the
guide, SWR's are permanent and
nely low — 1.05 to 1.

Models 372 are priced from
00 to $375.00 depending on the
guide band.

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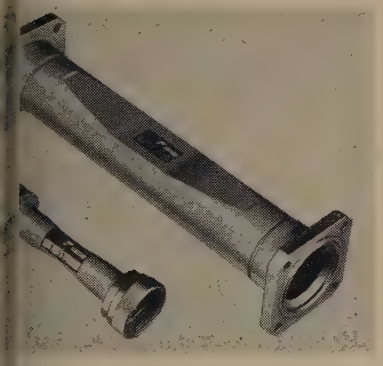
— m w j —

3 CYLINDRICAL WAVEGUIDE COMPONENTS



Mornay-Bonardi 780 So. Arroyo
ay, Pasadena, Cal., is in production
line of cylindrical waveguide com-
ts which transform linearly polar-
waves to circularly polarized waves.
nits are used with the correspond-
ze of rectangular waveguide. Cylin-
components cover the same fre-
y ranges, and exhibit the same
band characteristics as equivalent
gular D-B components.

ee items are currently available.
first is a rectangular-to-cylindrical
tion used to launch a TE_{11} mode
eat purity in a cylindrical wave-
guide. The second item is a circular polarization phase shifter used to transform a linearly polarized TE_{11} mode in a cylindrical waveguide to either left- or right-hand circular polarization. The third is a conical horn which radiates or receives either a linear or circularly polarized wave for antenna testing. By using the phase shifter in groups of four, a means is provided for continuously changing phase through as many full cycles as desired.

Each type is available in a complete range of sizes to cover 5.85 to 90 kmc/sec.

Among the many new applications for these cylindrical components are uses in plasma diagnostics. The different behavior of circularly polarized radiation is employed to derive information on the interaction of plasma with a magnetic field.

Bulletin DB-530 will be sent on request.

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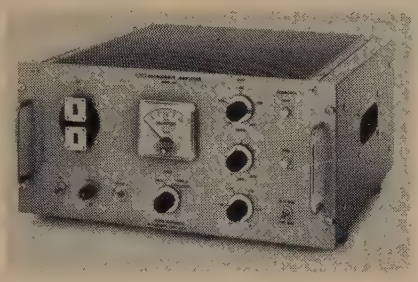
— m w j —

NEW ALFRED MICROWAVE AMPLIFIER



A new general-purpose microwave amplifier using a traveling wave tube for high gain over a wide frequency range is now in production at Alfred Electronics, Palo Alto, California.

Alfred's Model 549 offers broadband amplification with gain of 30 db and 10 milliwatts output from 10.5 to 16 mc. Use of a traveling wave tube, permanently magnet-focused, also provides versatile modulation features.

For example, a front panel connector is directly coupled to the TW tube grid for fast response amplitude modulation. In addition to usual AM modulation applications, such as gating and pulsing, the grid may also be used in AGC circuits to level power output.

Phase modulation, which is used in Doppler shift simulators and Doppler radars, may be accomplished simply through a front panel connector which is capacitively coupled to the TW tube helix.

Weighing just 33 pounds, the unit readily lends itself to bench mounting in laboratory or rack mounting for systems applications. Simple, rugged design, plus use of quality components in a conservative circuit, assures virtually trouble-free operation.

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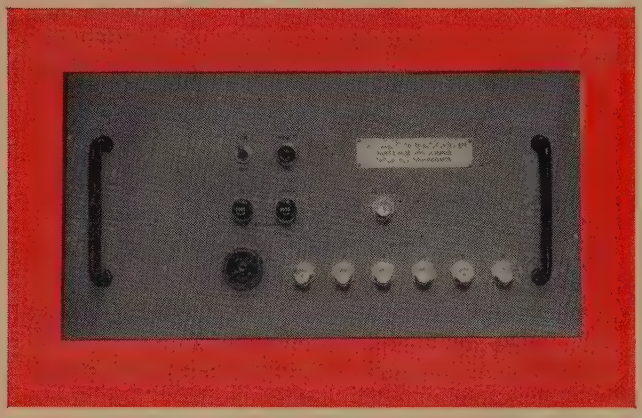
BROADBAND MULTICOUPLERS

30 to 1100 mcps

one to three octave bandwidth

maximum isolation—high gain

minimum noise figure—low power drain



Model HFM Multicouplers facilitate the operation of from four to 16 receivers from one antenna. They consist of a broadband, low noise, high gain amplifier followed by a passive multicoupler distribution system.

The multicoupler can be used in any type of communications system where it is necessary to operate two or more receivers from one antenna while maintaining maximum isolation between receivers.

TYPICAL PERFORMANCE CHARACTERISTICS

Model	HFM-6(AC)-326	HFM-12(A)-50110
Frequency Range	30—265 MC	500—1100 MC
Gain	>10 DB	>10 DB
Noise Figure	6 to 8 DB	7 to 11 DB
Number of Outlets*	From 4 to 16	From 4 to 16
Isolation*	>30 DB	>30 DB
Peak to Valley Ratio	±1.5 DB over band	±2 DB
Input and Output Impedance	50 ohms	50 ohms
VSWR Input	1.5	1.5
VSWR Output	1.75	1.75
Power Requirements	105-125 VAC	60 CPS

*To customer requirements.

Applied Research inc.

76 South Bayles Avenue, Port Washington, N.Y.
Phone: POrt Washington 7-8707

Books of Interest

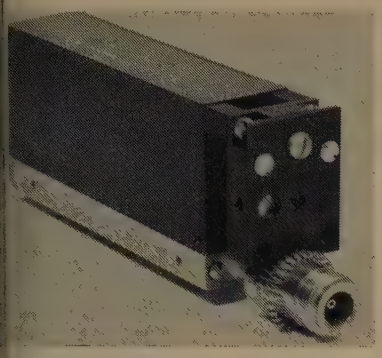
PARIS SYMPOSIUM ON RADIO ASTRONOMY, *edited by Ronald N. Bracewell. Published (1959) by Stanford University Press, Stanford, California. 601 pages, 10 index pages. $15.00. Reviewed by R. H. Kingston, Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Massachusetts.*

This book is a collection of 107 papers presented at the Paris Symposium on Radio Astronomy held at the Universitaire from July 30 to August 6, 1958, and sponsored by the International Astronomical Union and the International Scientific Radio Union. There are six sections devoted to the topics: Moon and Planets, The Sun, Galactic and Extragalactic Radio Sources, The Large Scale Structure of Galaxies, Discrete Sources and the Universe, and Mechanisms of Solar and Cosmic Emission. The conference itself was run in an eminently successful manner, a fact which is reflected in the completeness and coherence of the book. Each section was chairmanned by an outstanding authority in the field and all papers were presented by invitation. In addition, stimulating short discussions were recorded at the time and are included at the end of each section. The selection of papers, the large representation (162 scientists from seventeen countries), and the cited references (500 in number), make the work a standard reference in the field.

Since it was the expressed intent of the committee to exclude detailed descriptions of techniques, the book is not a primary source of information on the microwave techniques in this field; however, the numerous references should supply a wealth of information on these aspects. Such new approaches as the use of a solid-state maser in a radio telescope (Alsop, Giordmaine, Mayer and Townes) have been included and give the reader a glimpse of the advantages and present limitations of this new device. Of more general interest are the discussions of moon reflection, the radio behavior of the sun's atmosphere, radio-star and hydrogen-line observations, and galactic structure. The last two of the six sections are mainly devoted to experimental and theoretical questions of cosmology. The radio-source counting technique as a means of verifying or disproving the steady-state theory has as yet borne fruit, while the origin of radio emission and cosmic rays is now definitely associated with synchrotron action, although the prime energy source and magnitude are not clearly understood.

For a conference proceedings this is a surprisingly readable book. In particular, the introductory and concluding lectures in each section, which set the stage and then summarize the action, make a readable story in themselves.

IABLE COAXIAL ATTENUATOR, ZERO INSERTION LOSS, WIDE BAND



errimac Research and Development, 584 Washington Avenue, Belleville, Jersey, announces the development flat coaxial attenuator, covering band widths, with flat attenuation-s-frequency characteristics, continu-adjustable attenuation, and essen-zero insertion loss.

e unit features provisions for panel nting, in-line shaft adjustment, and ect reading, calibrated dial.

is unit meets the following specifi-ns:

) Frequency Band: units are avail-e with band widths of 4-7 and 1 kmc.

) Attenuation variation with fre-ency less than ± 5% expressed in

VSWR on all settings less than

) Power handling capacity: four tts average power.

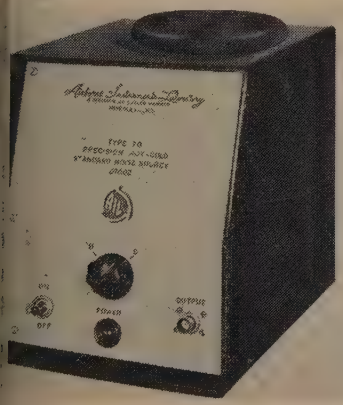
ese new attenuators are now de-d to produce a maximum of 40 db ttenuation in the above frequency s. The design, however, can be ex-d to produce up to 100 db of at-tion with flat attenuation-versus-ency characteristics.

renuation-versus-frequency character-with either positive or negative can also be provided.

cle Reader Service Card 126

— *m w j* —

OT-COLD BODY STANDARD NOISE GENERATOR



e AIL Type 70 Hot-Cold Body lard Noise Generator, designed and manufactured by Airborne Instruments Laboratory, a Division of Cutler-Hammer, Inc., provides a standard reference of excess noise temperature. Use of this device permits the measurement of noise figure to an accuracy much greater than previously possible with commercially available instruments.

The Type 70 covers the frequency range from 0 to 2000 mc with a relative excess noise temperature of 6.85 db (referred to 77.3°). The accuracy of the output is ± 0.08 db. The VSWR of each load is 1.15 max. with a maximum differential between loads of 0.02.

The cold load is maintained at the proper temperature by immersing it in liquid nitrogen. The hot environment is furnished by a thermostatically controlled oven. The switch between loads is also provided.

The unit is designed to operate with either the AIL Type 130 Precision Test Receiver or Type 74 Automatic Noise Figure Indicator, when used in the manual mode.

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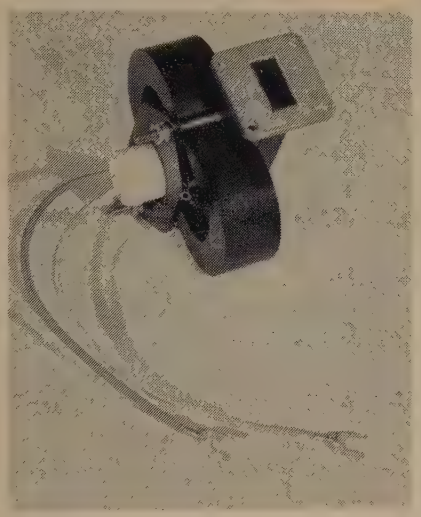
— *m w j* —

NEW LOW COST X-BAND MAGNETRON FROM RAYTHEON



The QK798 is a new, inexpensive X-Band magnetron designed for commercial applications such as small boat and small plane radars. The tube is a fixed-frequency pulsed magnetron of the non-integral magnet type with a probe output. The tube fits in a magnet and waveguide assembly which is supplied by Raytheon or can be manufactured from Raytheon drawings. Replacement of the tube is accomplished by loosening the thumb screws, removing the old tube, and inserting the new one. Location holes in the waveguide mate with studs on the tube to prevent improper tube locations. The tube is small and light, and since no integral magnet is necessary, storage and shipping problems are greatly reduced.

Specifications are available upon request.

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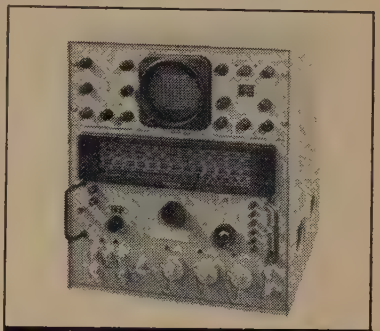
extreme sensitivity 10 mc to 44,000 mc



PANORAMIC'S SPA-4 SPECTRUM ANALYZER

MORE USEABLE SENSITIVITY

BAND	RF SENSITIVITY*
10 — 420 MC	—95 to —105 dbm
350 — 1000 MC	—90 to —100 dbm
910 — 2200 MC	—90 to —100 dbm
1980 — 4500 MC	—80 to — 95 dbm
4.5 — 10.88 KMC	—80 to — 95 dbm
10.88 — 18.0 KMC	—70 to — 90 dbm
18.0 — 26.4 KMC	—60 to — 85 dbm
26.4 — 44.0 KMC	—55 to — 85 dbm

*measured when signal and noise equal 2X noise

Using one tuning head which contains one triode and two Klystron oscillators, Model SPA-4 offers more exclusive advantages for applications demanding extreme sensitivity, stability, versatility, accuracy.

- **Three precisely calibrated amplitude scales—40 db log, 20 db linear, 10 db power.**
- **Two independent frequency dispersion ranges —continuously adjustable—0-70 mc and 0-5 mc. Negligible internal frequency modulation permits narrow band analysis of FM problems.**
- **Variable I.F. bandwidth from 1 kc to 80 kc.**
- **Push-button frequency selector.**
- **Synchroscope output with 40 db gain.**
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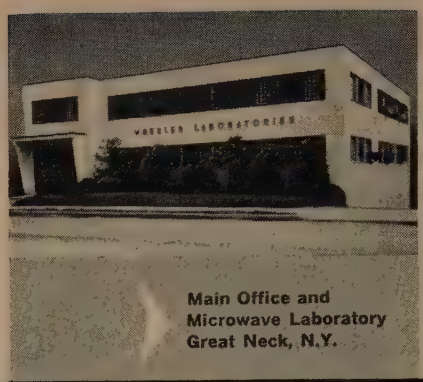

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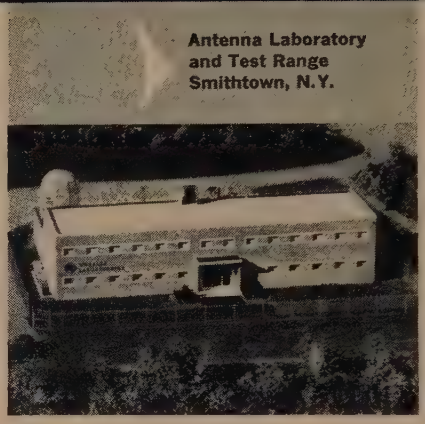

Antenna Laboratory and Test Range Smithtown, N.Y.

As a service to many prominent laboratories and manufacturers, WL designs radar and communication antennas, waveguide components, and microwave assemblies. Your inquiries are invited.

Harold A. Wheeler and Engineering Staff

WL

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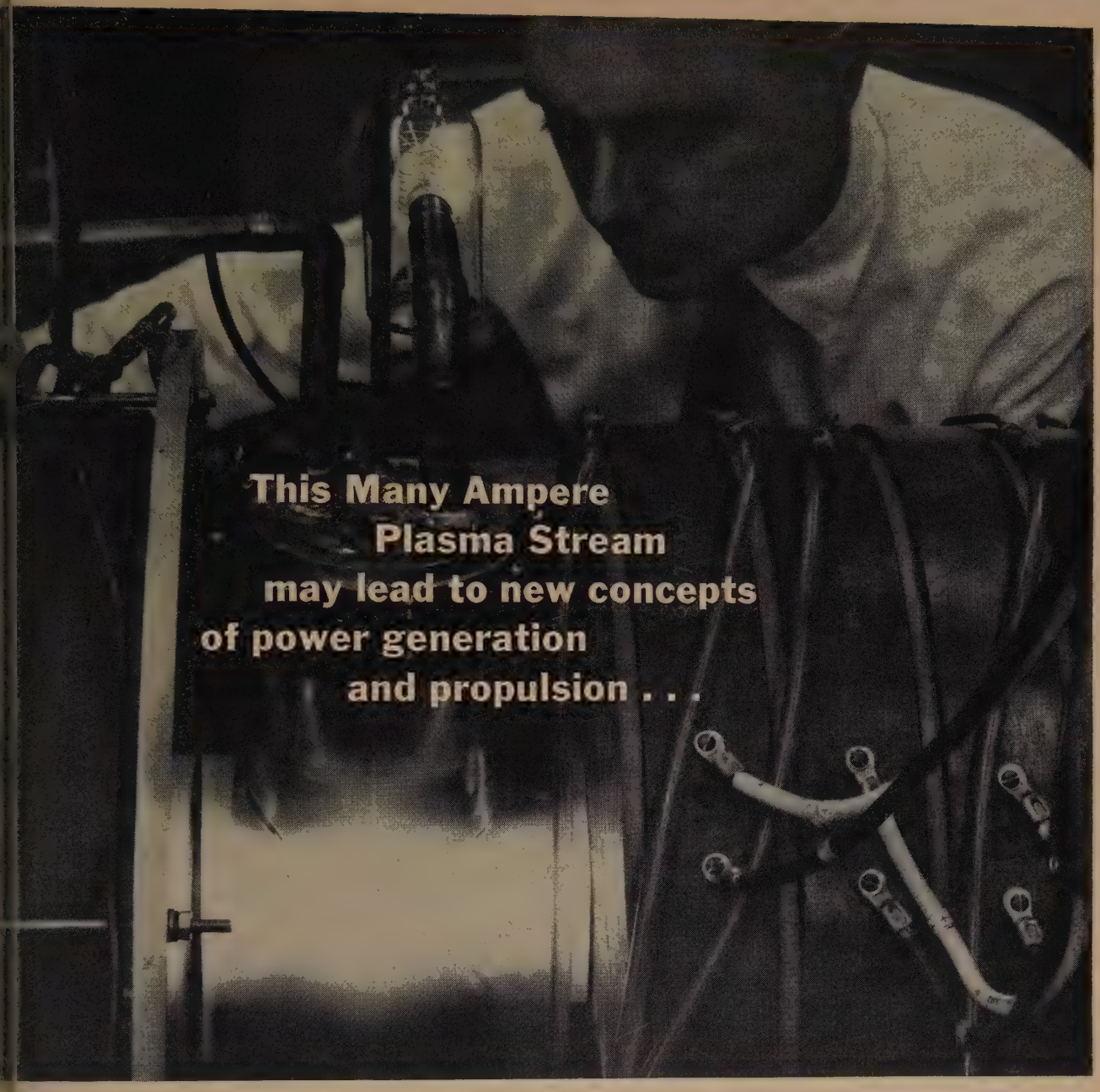

A many-ampere source of ions, this device is believed to be the most powerful in operation in any laboratory. Already it is providing new insight into thermonuclear fusion. It may lead to new concepts in propulsion including a method of producing thrust for missions beyond the earth's atmosphere.

Accomplishments like this are the result, we believe, of a unique research environment. Among other things, we encourage independence of scientific thought and action. And, we make determined efforts to free scientists from tedious routine — help direct their full mental powers towards scientific achievement.

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WEINSCHEL ENGINEERING
KENSINGTON, MARYLAND

BOX SCORE

NAME: Weinschel Engineering

LOCATION: Kensington, Maryland

PRODUCTS: Coaxial attenuators and terminations; insertion loss test sets; modulated r-f sources; antenna pattern measuring equipment; secondary standards for insertion loss, power and voltage.

HIGHLIGHTS: Having gained an unrivaled reputation as a manufacturer of extremely stable, precision coaxial attenuators, Weinschel Engineering is now winning recognition in the development of secondary standards for use as reference and working standards in research laboratories and production lines.

THE STORY OF WEINSCHEL ENGINEERING is one that offers a distinct contrast to the stereotyped image of successful companies that one comes to expect in this highly competitive age. For here is a firm that closed down a bare year after it had opened due to lack of funds — re-opened three years later because of the excellent rep tion of the product sold during that one year. Then, a re-opening, the company imposed restrictions upon i that, by all so-called "normal" rules of business, would hibit further expansion. Yet, today, the company tinues to grow physically, is expanding its product line, looks to the future confidently and in perfect health. us examine this seeming paradox and see what m Weinschel one of the outstanding firms in the microw industry.

Early Days

In 1944, while working for the Western Ele Company, Bruno Weinschel designed test equipment measuring insertion loss of small coaxial attenua Realizing the need for stable coaxial attenuators for at higher frequencies, Mr. Weinschel tried to inte his next employer, Industrial Instruments Co. of Je City, where he was Chief Engineer, in such instrum He did not succeed in this because of the firm's l interest in dc and low frequency measurements. Th fore, in 1948, he resigned and set up a small labora

The management of Weinschel Engineering: M. G. Domsitz, Albert L. Hedrich, Bruno O. Weinschel, Irving Feingold.

arch Physicists Sol Zimmerman and Phil Boesch review evelopment model of an r-f source and modulator with Chief Engineer Hedrich.

Brooklyn, N.Y. He succeeded in developing a stable nuator, but lack of capital forced the closing of the pany after a year's work. Mr. Weinschel then went work for the National Bureau of Standards in Washon. However, encouraged by the number of inies that continued to come in, and some purchase ers that arrived due to the performance of the atuators which had been sold in 1948, he resigned from and re-opened Weinschel Engineering in Kensington, yland in 1952.

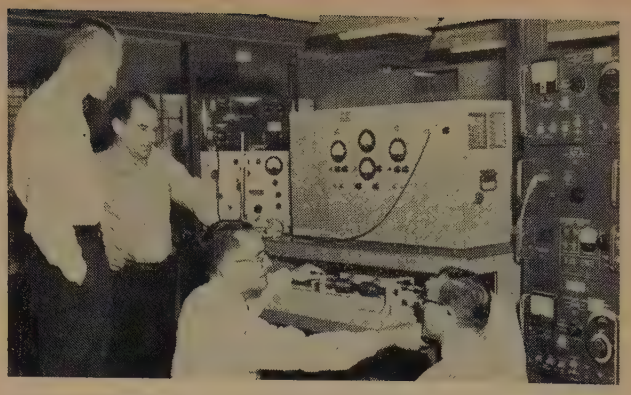
he company has confined itself rigidly to the manuure of instruments of high precision with entire phasis on quality and reliability, and stubbornly ses to embrace mass-production methods. Despite self-imposed disciplines which, on the face of it, ld bar further growth, the company, which in 1952 loyed five people, today employs over 140, and has ntly approved plans for a 30,000 square foot laborato be built near its present location in the suburbs Washington, D.C.

People

he main force behind this organization is Bruno O. nschel, founder and President. Weinschel, a physi- was educated at Technische Hochschule, Stuttgart, many, and did graduate work in physics at Columbia versity and Brooklyn Polytechnic Institute. He is ently working towards a doctorate in physics at rgetown University. A registered Professional Engi- in the District of Columbia, Mr. Weinschel is a ber of Commission 1, URSI and Chairman (1959-) of the Washington Chapter, IRE Professional up on Instrumentation. He is a senior member of IRE and a member of the following organizations: E, American Ordnance Association, American Asson for the Advancement of Science, American Physi- Society, and the American Institute of Physics.

econd in command to Bruno O. Weinschel is Execu- Vice President, M. G. Domsitz, who joined Wein- l Engineering in October 1959 to assume the insing administrative responsibilities brought about he growth of the firm.

omsitz, a graduate of Augustana College with grad- work in physics at the University of Iowa, was iously Vice President of Simmonds Aerocessories in ytown, New York. Before joining Simmonds, he Associate Technical Director of the Diamond nance Fuze Laboratories.



Research Physicists Don Pardue and Dr. Gunther Sorger, Bruno Weinschel and Electronics Engineer Walter Fischer use the "Standard Attenuator Comparator," Model VM-1B, for calibration of the output attenuator of a signal generator at 4000 mc and one microvolt.

In addition to his general supervision of all departments, Domsitz is responsible for guiding the sales efforts of the 16 carefully selected sales engineering organizations that represent Weinschel Engineering in this country and abroad.

Weinschel Engineering's Research and Development activities are directed by Vice President and Chief Engineer Albert L. Hedrich. Hedrich, who attended George Washington University, University of Maryland, and is now a graduate student at Johns Hopkins, was formerly head of a Technical Section in the Supporting Research Laboratory of the Diamond Ordnance Fuze Laboratories. He has published many major papers in professional journals, holds several patents and has others pending. He is a Senior Member of the IRE and has been Vice Chairman and Chairman of the Washington Chapter, Professional Group on Instrumentation, IRE.

Hedrich's R and D group is divided into four departments: *Standards Measurement Development* — Directed by Dr. Gunther U. Sorger, a physicist, who earned his Ph.D. (cum laude) at the Technische Hochschule in Stuttgart and taught a graduate course in electronics measurements there before he joined Weinschel Engineering in 1954.

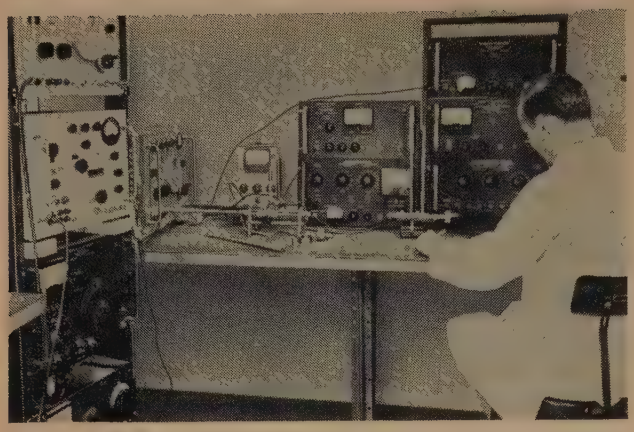
Coaxial Component Development — Work in this department is supervised by Microwave Engineer Julian F. Cottrell, who studied mathematics and physics at the University of Alabama and who was previously engaged in experimental work in high frequency equipment at the National Bureau of Standards.

Microwave Equipment Development — Headed up by Philip W. Boesch, who holds a B.S. in Physics from the University of Maryland and is a veteran of 10 years experience in research at the Diamond Ordnance Fuze Laboratories and the National Bureau of Standards.

Industrial Controls Development — This group is led by Don R. Pardue, who has an M.S. in Physics from the University of North Carolina and is working for a doctorate at Catholic University. Pardue was with the National Bureau of Standards and the Diamond Ordnance Fuze Laboratories for six years.

Products

Weinschel Engineering's first products were coaxial attenuators, and today the firm makes a full line of coaxial attenuators in the frequency range of dc to 12.4 kmc.



Microwave Engineer Jim Cottrell, Head of Coaxial Component Development, with a typical test set-up used in the development of broadband coaxial components.

These attenuators have earned a high reputation in laboratory and field applications in civilian and military establishments all over the country.

In order to maintain long-term stability of the coaxial attenuator line, Weinschel makes its own microwave film resistors; long experience in this specialized field produces resistors which the company says are characterized by excellent longevity and are virtually insensitive to atmospheric influences.

The main reason for the growth of the company is its expanding line of electronic instruments. This equipment was originally developed by Weinschel for test and calibration of its own precision attenuators, since existing equipment was found to be inadequate. Soon, other laboratories demanded these "tools" and a new and important part of the business was born.

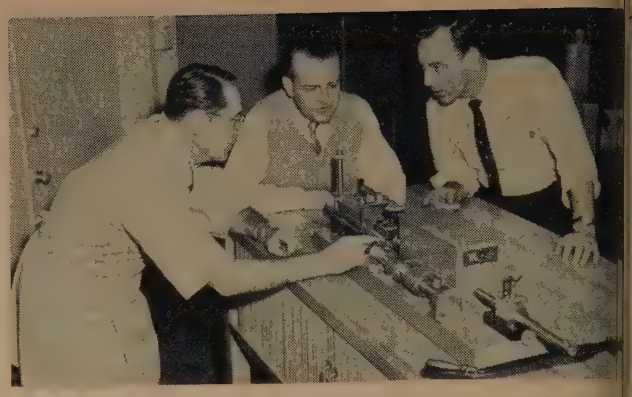
In this category are instruments for the measurement of insertion loss, modulated r-f sources in the range of 50 to 10,500 mc, and antenna pattern measuring equipment.

Research and Development

R & D is regarded at Weinschel as the company's most important activity. "Since we are primarily an organization of scientists," Weinschel says, "we are professionally interested in research; since we must also be businessmen, we are well aware that we cannot survive as an organization unless we continually develop the new instruments required by our customers and the advance of the microwave art." To this end, the company has brought together a group of exceptionally well-qualified physicists and engineers, given them proper supporting personnel and facilities, and allowed them maximum freedom in working toward the company's general objectives.

Facilities

Company facilities are located in two adjacent air-conditioned buildings with a total of 16,000 square feet. One building houses administration and production, the other the research and development laboratories and a model shop. Economies in time and motion have been achieved by attention to efficiency in layout — a must for a growing company that cannot afford the waste of even a few square feet of working area. The problem of space awaits a real solution with the building of the planned 30,000 sq. ft. structure, which will be located on a twenty-acre plot to allow room for future expansion.



Discussing the precision piston attenuator of the Model VM Standard Attenuator Comparator are Model Shop Forem Homer Evans, Chief Mechanical Designer Don Crate Mechanical Engineer Jack Drew.

Location of the plant in Kensington, Montgom County, Maryland, immediately north of Washington, D the management believes, is an important factor in he ing them produce better instruments, by allowing them attract and retain better scientific, engineering and te nical personnel than they could in many other locati Montgomery County is said to have the highest ratio scientific and management personnel, as well as the high family income of any county in the U.S.; and proxim to the scientific, education and cultural facilities of greater Washington area is a distinct advantage.

Quality Control

Weinschel will not permit the slightest deviation fr an extremely exacting system of quality control. Beginn with a rigid inspection of all materials and compone as they are received, each instrument is inspected tested in various stages of its manufacture. The conc of statistical quality control is rejected by Weinschel, w insists 100% test and inspection. The company's accounting indicates that fully 30% of the man-hours quired to produce an instrument are devoted to test inspection; but Weinschel feels that the results are w worth the cost.

Future

A successful combination of scientist and administra Bruno Weinschel has brought Weinschel Engineer through a period of unusual growth without resorting public stock offerings. Company policy does not sanct the release of sales or profit figures; but it has been in cated that 1960 sales will pass the two million dollar m After 1960? Weinschel feels that the present growth can be continued if he can preserve his present h standards of quality as production volume increases, an his R & D department continues to develop instrum with significant advantages.

Weinschel Engineering intends to grow in the attenu business, in the electronic test and measurement busin and most of all, in their newest field of interest, secon standards. How much will the company grow? This pends on its ability to obtain personnel of the cal needed to enlarge the organization without any sacri in performance. The growth pattern will be pretty r as it has been in the recent past — for Bruno Weins does not intend to dilute his ownership nor sacrifice q ity for the sake of simple growth.

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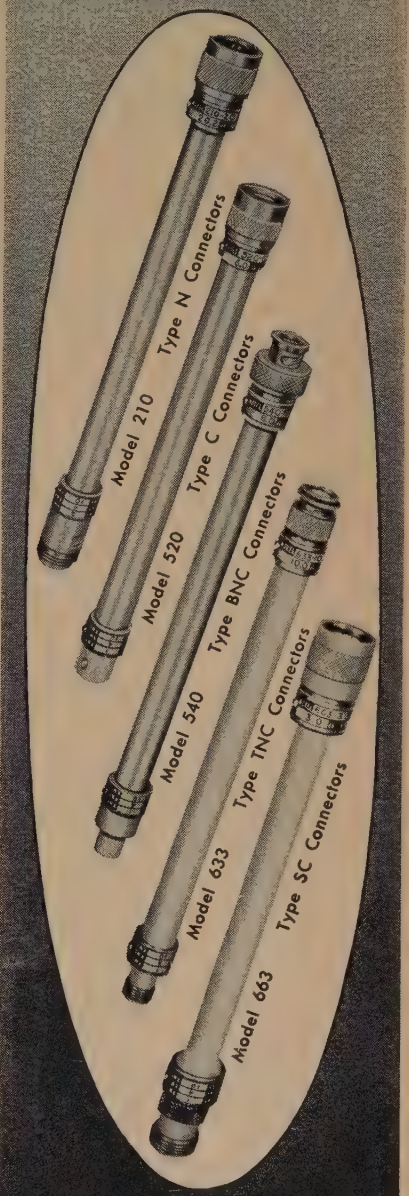
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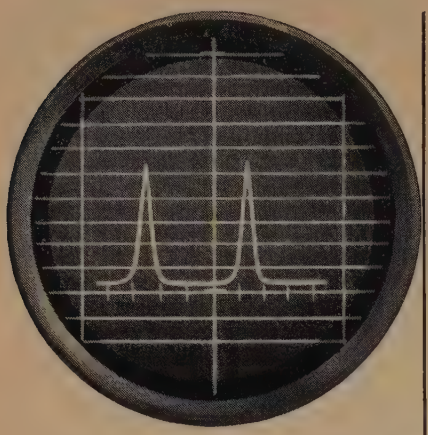

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RGANIZING FOR "PRODUCT PROFIT"

PALMER DERBY
ASSISTANT MANAGER
Spencer Laboratory · Raytheon Company

VERY BUSINESSMAN UNDERSTANDS dollar t. This is a symbol of his success. However, with t proper understanding of all the complex factors nsure this profit dollar, it may become pretty illusive, cularly when R & D is involved. To believe that the rules for minimizing manufacturing costs can be to maximize R & D payoff is folly. If there is to be h degree to creativity or "product profit" from the D effort, this will be achieved only through organ- nal and operational concepts built primarily to ac- nodate the professional engineer and scientist.

the microwave field today where markets are ex- ly dynamic with short product lifetimes, the R & D ion has become increasingly important. In the face mpetition, many companies have been forced into idly expanding R & D effort, which, in many in- es, instead of building dollar profits, has seriously ased them. With an increased ratio of R & D to facturing, the tendency is to make the R & D a center instead of a product source.

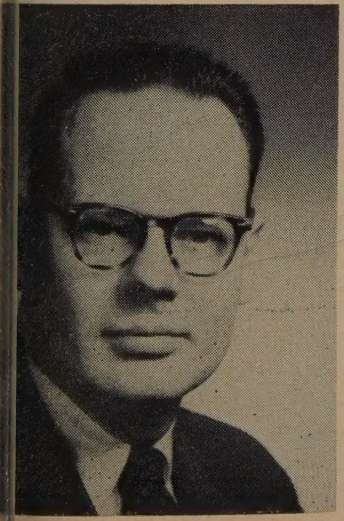
hen this profit burden develops, the business envir- nt rapidly changes from one of "we don't expect ke money from R & D" to "we must have profits R & D if we are to survive." Turning to the con- of a manufacturing enterprise for a solution to roblem is of little value. Even at best, these con- are short-term devices which destroy the creative nment rather than encourage its growth.

erating R & D so that it is a minimum burden to verall operation of the business, is important. How- the "product profit" of this function is far more icant than the dollar profit. If the overall creativity is not sufficient to supply products which will insure a well-balanced manufacturing and R & D effort, the long-term effect on dollar profits will undoubtedly be catastrophic.

Although there are many factors which can contribute to the creativity or "product profit" of a research and development effort, perhaps the most significant is that of organization. Since there is a long history on problems associated with the organization of manufacturing units to achieve maximum economies, there is always a strong tendency to apply these same principles to research and development laboratories. Since minimum product cost and creativity are extremely different things, they must be viewed as such if a real "product profit" is to be achieved from laboratory activity.

Most engineering organizations feel that a choice must be made between some type of project organization on the one hand and a purely functional scheme on the other. In practice, however, neither of these extremes can really exist. Even in companies which have attempted to formalize their organizations in either extreme, elements of the divergent concept are readily observed. This usually occurs as a result of evolution — not because of original planning.

Consider a typical systems development organization, for example, where the project system is employed. There may be several groups, each charged with the responsibility of developing complete electronic systems. In time, it is usually found that one of these groups will develop certain proficiencies in a particular component such as a radar-type receiver. This competence can and will expand to the point where a functional group is developed that will handle this technology for the en-



PALMER DERBY

Palmer Derby is the Assistant Manager for the Spencer Laboratory of the Raytheon Company. Since starting his career with Raytheon in 1942, he has been continually engaged in the research and development of microwave tubes. For his work during World War II in the field of magnetrons suitable for use in electronics countermeasure equipments, he received a Commendation from the United States Navy.

In later years he headed the team of engineers assigned the responsibility for development of the RK6249 magnetron, a high power, tunable X-band tube which is currently used in many airborne radar systems.

In 1954 he was appointed Manager of the Microwave Power Tube Research and Development Laboratory, the major tube laboratory in Raytheon's Microwave and Power Tube Division. Early in 1957 he assumed the responsibility for planning, building and organizing the Division's new Spencer Laboratory on Route 128 in Burlington, Massachusetts. This Laboratory, which was occupied in April of 1959, provides in its 150,000 square feet of space some of the most modern facilities for the research and development of all types of microwave tubes.

tire organization. Thus, when we examine such an organization critically, we find that although it may be clearly described as being project orientated, it has formed functional areas through an evolutionary process. On the other hand, if we were to view an organization which claims to be basically functional, we would often find individuals in each functional area who become identified with a specific project. When the project identification is sufficiently strong, an efficient, though informal, team is formed without any conscious effort on the part of management.

These tendencies which apparently contradict the working relationships described by the formal organization chart contain what is believed to be the most important point in the consideration of an effective laboratory unit. This is, where the organizational objective is creativity, the framework must be one which highlights the individual. In this way, an environment can be created which will permit him to achieve objectives in a minimum total elapsed time at a minimum cost. Besides these elements, which are readily recognized as the criteria of a good organization, the individual is in a better position to grow according to his capabilities. Since the pressure of the world environment, both from product competition as well as national survival, requires not only the effective use of personnel now, but also the continued growth of our engineering capability, such growth is essential.

It would be just as foolish to wring every profit dollar from a business without any planning for growth as to attempt to extract a maximum contribution in a short span of time from the R & D function. Any consideration of organization, therefore, must include the effect that it will have on the individual's growth and satisfaction in accomplishment as well as on his ability to meet the demands of the job to be done. Only with prolonged and satisfying contributions by the individuals involved can it be expected that a continuing maximum in output from the group will be achieved.

Certainly, such requirements could in their extreme be visualized as producing an organization so complex and confused that any management control would be difficult to administer. This, it is believed, is not necessary. Actually, were the organization to reach this extreme, it could not fill the human need for organizational security and would then as a consequence, be as detrimental as any rigid system for arbitrarily defining jobs and responsibilities.

What does all this mean? How, then, should an organization be formed? Starting with the simple maxim that "product profit" is essential and that this requires recognition of people for realization, it is believed that some very basic concepts can be evolved which can be utilized to build an effective laboratory unit. It may seem from the management point of view that these ideas may be in conflict since organizational control and individual freedom are not necessarily compatible. Certainly, neither a concept designed for simple organizational control nor one which gives the individual complete freedom of activity is satisfactory. In between these two extremes, however, is a large area which permits perceptive fitting between the individual's requirements and those demanded by the necessity for organized effort. Thus, it can be seen that what is seemingly a paradox is not really one at all, but rather, a challenge to management to organize the R & D effort to permit the m mum individual expression.

Perhaps the most natural way to approach the org ization for R & D, then, is first to consider the indivi and how he can be most productive. In most organ tional situations, there is an engineering need for con uing support as well as a longer term and sporadic used "library" of technical assistance. These elem are not unrecognized, for many organizations can rea point to integrated project teams supported by en eering service functions. Nevertheless, if a critical v were taken of the operation of these organizations would be readily discovered that the functions were tablished primarily for management control and funct economy. A reduced management burden and a m efficient use of engineering support time bought at expense of productive engineering time certainly not improve the "product profit."

Rather, the engineer or scientist must be viewed f What does he need for his day-by-day support? If must negotiate on a daily basis for personnel or fa ties, this is lost time which is repetitive and unrecovera His environment must supply these immediate ne but nothing more. He should not be burdened with management of little used technical support. Those sonnel and facilities which constitute his "library" technical support should be just that. Only as the c plexion of his program changes should his organiza environment change, and this it must do. To retain organizational rigidity which precludes setting up t for the task at hand supports only a false economy an ever-increasing burden on the dollar profit of overall business.

Care should also be taken not to let the "library" technical support degenerate into a scientific pool talent which awaits assignment to individual tea Should this occur, the development of supporting de in technology will be lost. This is just as disastrous, pushing the "art" and setting the stage for "br throughs" usually comes as a unique combination present knowledge. If advanced systems, equipm and components are to result in sufficient volume f the laboratory to insure a "product profit," then cannot wait for a nebulous invention. It must be the sponsibility of an area such as a technology "library produce the bits and pieces that will make possible assembly of a new whole. This group must then be position not only to contribute to today's projects, must also be generating at the same time the knowl for the unknown projects of tomorrow.

Organizing in such a manner is, of course, not w out its problems. Insuring day-by-day support prod a fluid organization with many potential conflicts can tax the best of managements. Uniform loadin personnel and facilities are neither readily planned stabilized. Eliminating duplication of effort or eq ment is practically impossible. But since these probl are only of secondary importance to the need for creased technical productivity, they are worthwhile t endured. Certainly, closely integrated teams unclutt by elements of functional management can move wi speed where results are rapid and rewarding. The e on morale and the overall tenor of the organizatio obvious.

RADAR AND REVOLUTION

One sweltering July afternoon in 1789, a tattered raggedy mob appeared outside the gates of the Bastille, the formidable prison of Paris, and demanded entrance.

"Go away," the guard shouted, "or we'll have to arrest you."

"That's exactly the idea!" a voice came back. "We're starving to death. All we want is a little of that moldy bread and canal water you feed your prisoners!"

Word was passed to the prison commandant, one Maurice Antoinette. "If they want their just desserts," he smiled, "let them eat cake!"

It was this remark that sparked the Revolution. The mob grew ugly. "Force the gate!" shouted a sickle-wielding daughter of France named Brigitte Sourdough. A radar controlled battering ram, appropriated from the local armory, swung into play. In moments, the Bastille gate had been hammered into shambles, and the unfortunate Maurice Antoinette was at the mercy of the mob.

"Observe the instrument of your defeat!" sneered Brigitte Sourdough, pointing at the radar.

"Pfui," the commandant replied, calm and disdainful. "No Beaumac (French for Bomac) tubes."*

Brigitte was furious. "The commandant wants 'Beaumac'? He shall have Beaumac!"

With that, Antoinette was led to a second instrument of the people — a device consisting of a heavy blade, poised between grooved uprights. It had no tubes at all.

"This is your Beaumac?" the commandant asked.

"Oui, monsieur," Brigitte Sourdough leered. "This is Beau Mac — the knife!"

No sooner had Maurice Antoinette heard these words than his icy calm vanished.

Matter of fact, he lost his head completely.

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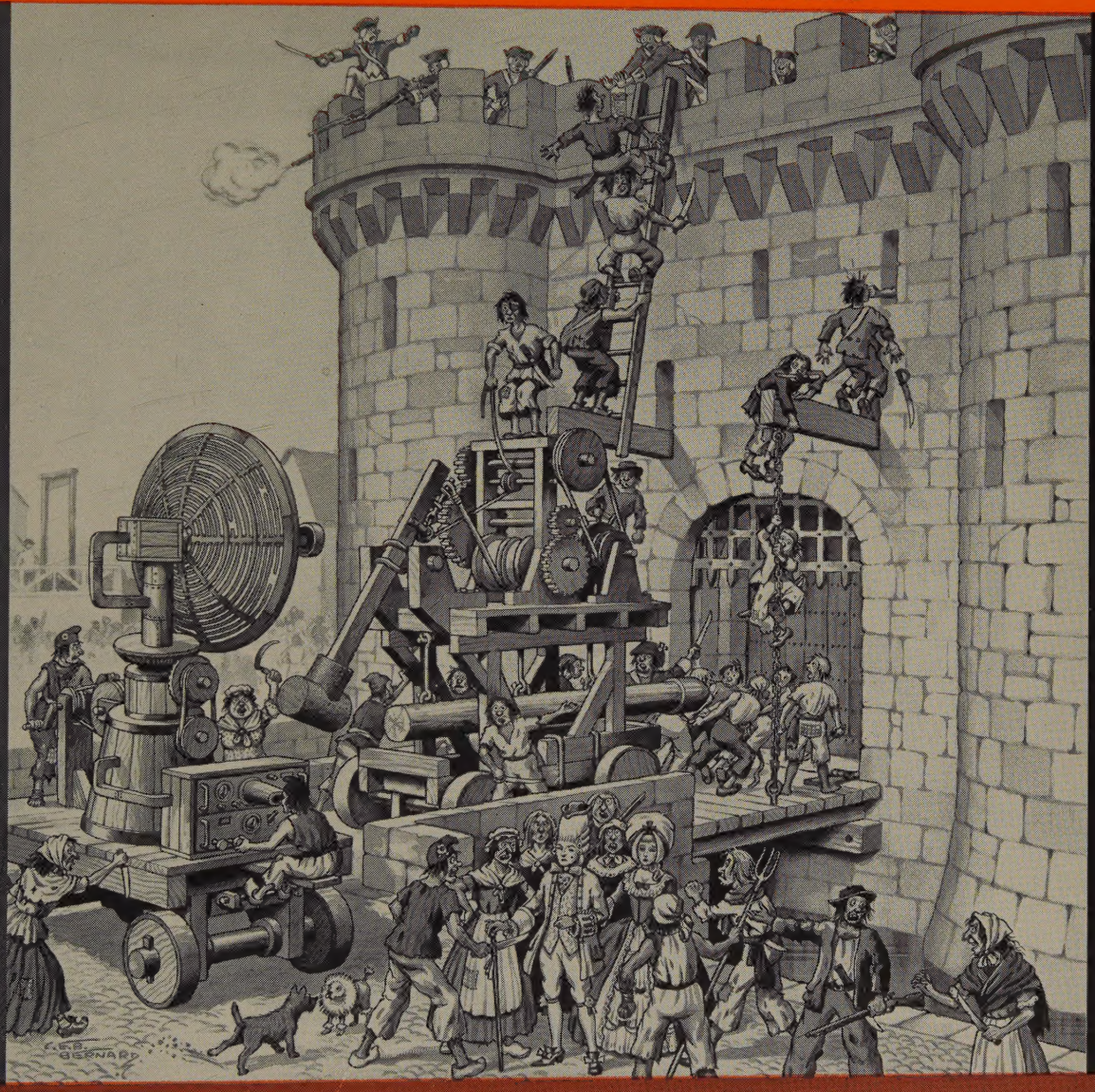

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